

**FIRE SPRINKLER PLAN REVIEW CHECK LIST
AND GUIDE FOR PLANS REVIEWERS**

FIRE SERVICE FINANCIAL MANAGEMENT

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ABSTRACT

Cheyenne's Fire Prevention Bureau (FPB) does not have a standard for the review of fire sprinkler system plans. The bureau has recently hired a civilian plans examiner, whose job includes the responsibility to review fire protective systems. The new plans examiner has no experience in reviewing fire sprinkler systems, nor the experience of conducting any of the acceptance tests for the system's installation.

The purpose of this research project was to develop a review process consisting of a checklist and guide for the plans examiner to utilize for the review of fire sprinkler systems plans.

The action research method was employed to answer the following questions:

1. What statutory codes, standards or local rules apply to fire sprinkler system design and installation?
2. What specialized training or certification requirements should be required for a fire sprinkler system: (a) designer, (b) plans reviewer, (c) installation contractor, (d) maintenance company, (e) inspection personnel?
3. What constitutes a complete and reliable fire sprinkler system?
4. How are the different types of fire sprinkler systems to be installed in the different occupancies determined?
5. Which elements of fire sprinkler requirements have the greatest potential to be misapplied or to cause failure?

The procedures used to complete the research included a literature review of fire service journals, textbooks and magazines relating to fire sprinkler systems. State statutes relating to the authority of the State Fire Marshal's (SFM) Office, statutes concerning architecture, City Code in relation to Chapter 17 Fire Prevention, fire department rules and records concerning fire sprinkler systems, and rules of the Contractor's Licensing Board (CLB) concerning the licensing

of fire sprinkler contractors, were reviewed. Personal interviews with professional fire protection specialists, designers, installers, and trade associations were conducted. The result of the project was the creation of a fire sprinkler checklist and guide, and additional rules being added to the contractor's licensing requirements. Recommendations were to implement the use of the checklist and guide, with a review and evaluation of this process to be made after the plans review course to be given by the National Fire Sprinkler Association and a year after that. Fire sprinkler classes and training are to be provided to the civilian plans examiner and each fire inspector that might be reviewing fire sprinkler plans, witnessing the acceptance test, or conducting inspections on the systems. Future plans are to have the new plans examiner and fire officers attend formal classes in fire sprinkler plans review.

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INTRODUCTION

The Cheyenne Fire and Rescue's Fire Prevention Bureau (FPB) does not have a standard process or procedure for the review of fire sprinkler plans. Lack of an established policy regarding the plans review for fire sprinkler systems and no prior training or exposure to the requirements for the system's design, posed difficulties for the new civilian plans examiner who is responsible for performing the reviews.

The purpose of this research project was to develop a review checklist and guide for plans reviewers to utilize when conducting fire sprinkler systems plans review. The action research method was used to answer the following questions:

1. What statutory codes, standards or local rules apply to fire sprinkler system design and installation?
2. What specialized training or certification requirements should be required for a fire sprinkler system: (a) designer, (b) plans reviewer, (c) installation contractor, (d) maintenance company, (e) inspection personnel?
3. What constitutes a complete and reliable fire sprinkler system?
4. How are the different types of fire sprinkler systems to be installed in the different occupancies determined?
5. Which elements of fire sprinkler requirements have the greatest potential to be misapplied or to cause failure?

The procedures used to complete this research were a literature review of fire service journals, textbooks and magazines, a review of City of Cheyenne documents and records, a review of statutory requirements, and interviews with fire sprinkler systems technical specialists.

Results

A fire sprinkler system checklist and guide was developed for Cheyenne's Fire & Rescue (CF&R) plans examiners to use in the review of the shop drawings being submitted for these systems. New rules were proposed to the Contractor's Licensing Board (CLB) concerning fire sprinkler system designers and contractors.

Recommendations

The checklist and guide should be implemented and a follow up evaluation conducted after the fire sprinkler course on plans review to be conducted in September of 2002. The checklist should be revised after the plans review class and then evaluated and revised as necessary each year. The plans reviewer should be required to take formal classes concerning fire sprinkler system's design, installation and maintenance courses, and certify as an International Council of Building Officials (ICBO) plans examiner.

BACKGROUND AND SIGNIFICANCE

Since the inception of the fire prevention bureau of the City of Cheyenne in 1979, the construction plans examiners for the fire department have had little formal training to prepare them to conduct fire protective systems review, especially concerning fire sprinkler systems. The plans reviewer position was, in the past, held by a fire department officer of the prevention bureau. The fire officer historically worked his way through the ranks in the suppression division, where he gained working or institutional knowledge of firefighting operations and through the training officer would be introduced to fire protective systems operations only.

During the fire officers' careers, as code enforcement lieutenants, they learned fire safety construction application through on-the-job training. As a code enforcement official, they were exposed to fire protective systems that were installed in buildings they were to inspect.

The only training they had received on fire sprinkler systems was by reading International Fire Service Training Association (IFSTA) training manuals, the National Fire Protection Association

(NFPA) 13 Fire Sprinkler Code, and asking questions of fire sprinkler installers and maintenance contractors. In the mid 1980's, the lieutenants of prevention started attending the National Fire Academy's (NFA) courses in fire prevention. Everyone that has had the duties and responsibilities to conduct the fire sprinkler systems reviews since then has attended the (NFA) "Structures and Systems" course, an introductory course on fire protective systems. Even with this course, they have not been fully qualified to have conducted the fire safety systems reviews.

From 1979 to date, the plans reviewer was expected to perform the fire sprinkler system review utilizing the Uniform Fire Code (UFC) and the other uniform body of codes, in conjunction with NFPA 13. The reviewer received on-the-job training and, if time permitted, would attend, if accepted, the NFA course or courses for fire inspector and plan review, according to past Fire Chief, Piester. Because of a lack of knowledge and the complexity of the fire code's requirements for the design, layout, installation, and maintenance of fire sprinkler systems, the plans reviewer has continued to pass down the same problematic procedures and practices concerning the review of fire sprinkler systems. This in turn has affected the system's installation, acceptance testing and maintenance.

The shortage of personnel in the bureau made it difficult for this author to develop written instructions, checklists or guidelines as none were in existence previously. As the technology, scope, and demands of the regulatory process expand, the more expensive and demanding it becomes for municipalities to fulfill their obligations. With limited resources available, it becomes a matter of necessity for local governments to fulfill their obligations based on a perception of those requirements which are relatively absolute in nature and those which can be established on the basis of priorities reflecting apparent accepted risk balanced against community benefits. (Remmer, 1978, p. 366).

Historically only limited numbers of the department's firefighters have been interested in a

career in the FPB. This is in part due to the workload and the lack of comparable compensation under the department's contract. It generally takes an individual four to five years to acquire the training and background experience in code enforcement, construction plans review, fire investigation and related fields to be able to function independently in the FPB. Years of specialized training and education are required to acquire knowledge in the specialized areas of fire protective systems such as fire sprinkler systems. As such there has been a great responsibility placed on the person conducting the plans review on these systems.

The author found that he and the personnel in the bureau had not properly identified all of the problems relating to fire sprinkler plan reviews and other requirements concerning these systems. The fire prevention bureau's staff has been working to identify all problem areas in the FPB. These include problematic fire alarm systems, plans reviewer position qualifications, fire protective systems review such as fire sprinkler systems review, certified code inspectors, and training of personnel to qualify them to perform their job functions. Efforts to correct these problem areas have been on-going since 1996.

The rules for licensing of fire sprinkler contractors and installers in the past have been very lenient. All that was required was taking an in-house written test. (City Contractor's Licensing Board rules). Testing for the license consisted of only a few questions and was an open book exam written from out of the 1986 NFPA 13 code. The candidate was given two and a half hours to complete the test, which was very general in nature.

Licensing requirements for fire sprinkler contractors and installers were changed by the author in 1997 under the CLB's rules and approved by City Ordinance. All fire sprinkler contractors and installers must now pass a City fire sprinkler examination. The exam was written to test the practical nature of fire sprinkler installation applications from the NFPA 13 code. The Board chose to make the test an "open book" exam. As part of the prerequisite requirements to

apply to be a “Qualified Supervisor” the contractor’s representative only had to show proof of having work experience of four years in a related field, such as plumbing. The author requested that this be changed, that all new applicants must show proof of having four years of work experience directly related to the installation and/or maintenance of fire sprinkler systems. Those contractors already licensed were “Grand Fathered”, by the Licensing Board, including plumbing contractors.

To date, licensed contractors are not required to retest nor have a certain number of continuing education hours or code course work within a specified time limit, they only had to keep current on annual fees for the license and to maintain proof of insurance.

No specialized training on fire sprinkler systems or knowledge of the codes was required as a prerequisite for reviewing the submitted sprinkler plans. The fire sprinkler designer was not required to be certified. Wyoming state statutes require, according to the State Fire Marshal’s (SFM) assistant, Dubai, all construction plans submitted for review that are commercial, over one story, and not exempt as agricultural, contain a stamp from a licensed professional engineer, that is registered in the State of Wyoming. D. Dubai (personal communication, May, 2002). This statute was, however, seldom enforced by the City’s Chief Building Official. If submitted, the fire sprinkler plans that reached the FPB’s plans reviewer were seldom rejected, even if the fire sprinkler plans were incomplete. This was because of a lack of knowledge of the fire sprinkler code’s requirements. Past plans reviewers had received no formal training in the area of fire sprinkler systems and were not certified plans reviewers. It has been a “learn as you go” type of operation. The author informed the former Building Official back in 1997, that the fire department would accept National Institute of Engineering Technology (NICET) Level III technicians to be licensed by the CLB without testing. Additionally, a NICET III technician would be allowed to submit shop drawings for review with their certification number, but the

construction plans were required to be stamped by a Wyoming licensed engineer.

A year and a half ago, the former plans reviewer for the fire department retired. The author took over the responsibility of reviewing all plans submitted for platting, development, construction plans review for fire safety, and all fire protective systems and discovered, at that time, that no checklist or guide was being utilized.

The fire prevention bureau, through the union contract, negotiated to hire a civilian plans examiner in the 2001 contract. The fire department was to hire a "Fire Protection Engineering Technologist" (FPE TECH). The position was advertised by the Human Resource Director, but only on a local basis. Prerequisite qualifications for the position were provided with the announcement, which sought a person with a fire protection engineering degree. The position's pay range was set at \$32,000 to \$45,000 by the City Council. Of the applications that were received, no one had a fire engineering degree, and only one person had construction contracting experience and a little firefighting background. The applicant was hired for fear of losing the new position all together. It was the Chief's belief that the Fire Marshal could train the new civilian plans reviewer to perform the requirements of construction plans examination. No additional budget was approved for training however. The new civilian plans examiner was hired in September of 2001, but he had no certifications that would qualify him to conduct plans review, especially fire sprinkler systems. As a condition of employment, he had to be certified as an inspector in the UFC within one year of employment, which he accomplished six months after being hired. Additionally, he has to become certified as a plans reviewer within two years of hire, by the International Council of Building Officials (ICBO). The reviewer is being trained to conduct not only fire safety construction plans review but fire protective systems reviews as well, this includes the fire sprinkler systems review. Checklist and guides are in place for fire safety construction reviews, water supply, and fire alarm systems for him to utilize, but a fire

sprinkler systems checklist and guide has not been developed by the author yet.

The past affect of the problem is that a standardized fire sprinkler system plan review was not conducted on those systems that have been installed in the City of Cheyenne prior to August of 2001. The systems reviewed in the past and approved may have code deficiencies in the design and therefor in the system's installation. The reliability of existing systems prior to 2001 are considered suspect.

The suppression crews are in the future to conduct a survey during their preplan process, that may help in identifying if a fire sprinkler system is installed, and hopefully, which type or types exist and possibly the condition of the system so that this could be entered into a data base for inspection purposes.

The FPB has been concentrating its efforts on new construction projects at present, but still does not have a standardized checklist and guide to utilize during the review of fire sprinkler system plans. This could have a negative affect on the review in the absence of the Fire Marshal to assist the new plans examiner.

If the problem is not corrected, the future impact to the city and fire department is that it will have a negative impact possibly allowing improperly designed and installed systems to exist in the new buildings being constructed in the city. The department has taken a stance on not falling farther behind in this area by focusing on new and remodel projects only, at this time. The city is in a construction boom and is projected to grow by fifty percent over the next five years.

The credibility of the organization, concerning all fire sprinkler systems, will be the benefit of this project. The checklist and guide should help to ensure that the plans examiner and any other FPB personnel that may conduct a fire sprinkler plans review, conducts a standardized review. This should reduce the number of poorly designed and installed systems. The civilian plans examiner is to be provided a fire sprinkler checklist and guide, and training in the fire

sprinkler plans review process. This should add consistence to the review process and free up the author's time to concentrate on other areas of concern.

This project was undertaken in part to satisfy requirements for the NFA's Fire Service Financial Management Course, one of the Executive Fire Officer's courses. Several units were relevant to this project. Fundamentals of Budget from unit 2, Presentation unit 3 covered self assessment, and knowing your audience, which was beneficial in planning for the Contractor's Licensing Board rule changes and cost factors involved. Unit 4 covered financial planning, unit 5 covered forecasting, unit 8 covered budget management, unit 9 the council hearing, all of which applied to project in some form or fashion.

The department has forecasted its new budget seeking training dollars for the plans reviewer and other members. Previous budgets were analyzed and alternative funding sought, and presentations were made to the council. This project hinges on budget management, doing what we can in-house to improve the current situation concerning fire sprinkler plans reviews and to stay within budget. A properly designed fire sprinkler system has been proven to save lives, this project should aid in accomplishing this goal and falls in line with the US Fire Administration's operational objectives.

LITERATURE REVIEW

Fire service professionals take significant risks to perform their duties, and they get the immediate satisfaction of knowing that the risks they take pay off in saving human lives. Fire protection design professionals make a contribution no less significant. They are not only responsible for saving lives of people whom they will never meet, they help to significantly lessen the risk to fire service professionals by designing fire protective systems that prevent a fire from getting out of control. (Gagnon, 1997).

In an interview with SFM assistant Dubay, Dubay was asked what statutory codes apply to

fire sprinkler systems design and installation in Wyoming. Dubai replied that Wyoming statutes require all plans for buildings designed to be constructed, under the “architects” section of the state code that are over one story in height, are to be occupied by more than ten people, are commercial buildings, are not exempt as agricultural in nature, are required to be stamped by a Wyoming licensed professional engineer. (Dubai, October 1997). An architect or landscape architect shall affix his seal to all documents, plans or designs provided. (Wyoming Laws, 1991).

The researcher investigated the Wyoming statutes, and what the legal basis allowing for the enforcement of fire sprinkler system requirements were, and found the following: (a) that the Uniform Fire Code (UFC) is adopted by the SFM office by Wyoming statutes, (b) that the SFM is authorized to issue local municipalities, cities and towns “Home Rule Authority”, (c) that Wyoming statutes require the above to follow the “Administrative Procedure Act” in adoption of ordinances, (d) that Cheyenne City Code chapter 17 titled Fire Department, applies to the FPB within the jurisdiction of the City of Cheyenne, (e) that the City is authorized to amend such code by ordinance, to a more stringent status as deemed necessary for the local jurisdiction, (f) that the UFC 1997 edition was adopted in May of 1998 by the City Council, (g) that article 10 of the UFC 1997 edition applies to fire sprinkler requirements for the various occupancies listed in the code, (h) that Chapter 17 of the City Ordinance references NFPA 13 for the installation of fire sprinkler systems, which in turn references NFPA 170 Symbols for Construction Design, (i) that the Contractor’s Licensing Board for the City is appointed by the Mayor and is authorized as such to set rules and regulations for all contractors doing business within the City of Cheyenne, and (j) that all new or delinquent fire sprinkler contractors as of 1998 were required to take and were administered a written examination on fire sprinkler systems installation by the Licensing Board.

In an interview with the FPE Tech from Poudre Valley Fire Authority, Ron Gonzales,

Gonzales confirmed that even though Colorado does not have a SFM office, that each major fire department in Colorado has adopted the UFC and that NFPA 13 is used in the review and installation of fire sprinkler systems. R. Gonzales (personal interview, November, 2001).

The use of a checklist during the plans review and the inclusion of all appropriate agencies can also reduce the potential for an oversight. If no design professional is used, the code official has an increased responsibility to conduct a thorough plans review and to monitor the construction. As a result, many code officials require the use of a registered design professional. Case law, for the most part, assigns the responsibility for code compliance to the architect or engineer. (NFA, 1994, p. I-17-I-19).

Some may argue that the Authority Having Jurisdiction (AHJ) should be responsible for quality assurance. Those thinking this way should seriously consider that an error made by a designer or installer of a fire protection system is not absolved of responsibility if an AHJ misses the error. Most governmental AHJ's are immune from civil liability in cases of deaths caused by faulty fire protection systems, whereas designers and contractors are not. (Gagnon, 1997, p. 280).

In an interview with (FPE) Glen Saraduke, from Golden, Colorado, Mr. Saraduke said that to his knowledge most plans examiners in fire departments usually are certified by ICBO only in the UFC and rely on the Building Official's review for the UBC's portion of the plans review. The plan reviewer should be ICBO Certified as a plans examiner. If the municipalities are conducting joint reviews, there may not be a need for the duplication by the fire department to review for the UBC requirements for fire safety, if you are comfortable with their review process. This certification provides theoretical background in the UBC's application for review of construction designs. Fire safety plans review, requires a general background knowledge of blueprint reading ability. The reviewer must possess technical knowledge in the specific fire safety systems being

reviewed, with the ability to analyze the building code and fire codes applications to those systems. He or she should have additional working knowledge and background in the fire code and NFPA standards. The knowledge, skills, and abilities required to conduct a thorough plans examination, specifically for fire protective systems, is too broad of an area generally speaking for one plans reviewer. This requirement should be spread amongst several individuals in specific technical areas of the codes and standards. The person most versed in the area should review the plans for that system. G. Saraduke (personal communication, June 2001).

In an interview with PE Al Baker, an engineer with Schirmer Engineering, Al said, “I don't know that you will be able to find a place or someone willing to issue certification as a plan reviewer for fire protective systems. I've never heard of any. You know that ICBO has a certification as a plans examiner, or there is NICET certification as a engineering technician. Most fire department reviewers are satisfied with being certified by ICBO as plans examiners and hopefully in the UFC. This gives them a pretty good background if they've come up through the ranks. On really technical or specialized fire protective systems the vast majority rely on technical reports and consultation with either a design engineer and or a FPE. Third party review and acceptance testing usually are not the norm, but on very few jobs and specialty fire protection such as fire proofing of structural systems in high rise construction, where certification and or licensing is required by either the project engineer or the Building Official.” A. Baker (personal communication, March 2001).

In an interview with Ron Gonzales, FPE Tech, from Poudre Valley Fire Authority, Ron confirmed that most reviewers have come from the fire department and that you are lucky if they have the ICBO certification as a reviewer. His department and most along the front range of Colorado are hiring FPE Techs out of college to conduct the plans examinations, especially for the fire protective systems, “they’re just getting too complicated.” Denver and the larger

departments actually have FPEs on staff to review or supervise the plans review. R. Gonzoles (personal communication, April, 2001).

Interviews with Plans Examiners

Interview with Pat Westerhome, Wyoming SFM's Office, a ICBO Certified Plans Examiner. Pat said, "because I came from the Building Official side, I was already certified as a plans examiner. I'm not certified as a UFC inspector, although I've attended most of the seminars in the state for almost five years now. So I have a good background and knowledge of what to look for on the fire side. I don't have special training or background in fire protective systems, I've just attended the seminars and reviewed the code standards, when I do the reviews I find mistakes on the system designers part now and then." P. Westerhome (phone interview, March 2001).

After conducting phone interviews, it was discovered that none of the fire departments in Wyoming have ICBO certified plans examiners, particularly for conducting the fire sprinkler plans reviews.

Interviews with Fire Protection Specialist

Phone conversation with Page Dougherty, ICBO's Fire Protection Specialist. When asked what the requirements for more specific reviews concerning fire protective systems on the plans examination review, Dougherty said, "I'm not aware that there are any requirements for the ICBO Plans Examiner to have any specialty training to conduct these reviews. I do think they should take specialty seminars or college level courses in the specific fields of fire sprinkler system, fire alarm and others. NFPA offers these as well as the National Sprinkler Association, and Fire Alarm Association. NICET has a certification for technicians in those specific areas. I

would suggest you call Bill Hopple for fire alarm training, and Gene Indoff for sprinkler systems. I will tell you this. I think you have a legitimate point concerning the review of construction plans for fire protective systems and ICBO is conducting a staff study in that area, and is considering offering a certification for 'Fire Marshals' that will deal specifically with that, because to the best of my knowledge there isn't any certification offered anywhere. Contact the California SFM's Office. They have a great training program for fire prevention for inspectors, plans reviewers, and fire marshals." P. Dougherty (phone interview, August, 2001).

Interviews with Fire Protection Specialist

In a phone conversation with Gene Indoff, National Fire Sprinkler Association, Director of Codes, Gene said, "We, NFPA, and several technical colleges offer training in fire sprinkler system design and review. However, I don't know of anyone other than NICET or the other national certification outfit that offers certification.

We do present a certificate of attendance with our seminars." G. Indoff (phone interview, August, 2001).

Phone interview with Jodi Weyers, Oklahoma State University, Career Services. Weyers said, "All graduates have a strong background in fire protective systems. They may not specifically have certification in the specialty areas of fire alarm or fire sprinkler systems, but have taken courses concerning these areas and are able to conduct plans examinations for code compliance on these. All students are qualified at the time of graduation to sit for the general engineering technicians certification offered by NICET. Those that have worked or are working for specialty companies may qualify to test in the specific area for NICET certification, but that is not very often." (J.Weyers phone conversation, May, 2001).

This author did contact the Society of Fire Protection Engineers and found that they have an annual professional development week that covers very specific fire protective systems in

addition to fire alarm, and fire sprinkler systems. (SFPE, 2001). ICBO additionally offers a number of seminars related to the Building Code and Fire Code. There were several courses specifically offered in the area of plans examination for both fire and building, but nothing on specialty systems. (ICBO, 2001).

Gagnon specifies, by definition, what a fire protective engineer is. Fire protective engineers are qualified by experience and education to perform protective systems design. He further defines what fire protective system design is. Fire protection technicians are persons with the knowledge, skill, and training to perform fire protection layout, the act of following the requirements of a standard to execute a drawing using accepted national standards. (Gagnon, 1997, p. 17).

According to Gagnon, the NFPA, publishes over 290 codes, standards, recommended practices, and guides that apply to fire safety and the design of fire protection systems. (Gagnon, 1997). He specifically sites NFPA 13 to be used as a minimum in the design of fire sprinkler systems, NFPA 25 for the maintenance of water based fire protective systems, and NFPA 20 for fire pumps and NFPA 24 for private fire service mains.

In an interview with Glen Saraduke, a Fire Protection Engineer (FPE), he indicated that under NICET rules, only a NICET level IV technician is recognized to perform fire sprinkler system design. However, a level III technician can perform layout. The plans examiner should be trained and knowledgeable in plans review. It lends more credibility to the review if this person is ICBO certified as a plans examiner. He should have additional training and knowledge in specific fire specialty systems, such as fire sprinkler systems design. NFPA offers courses on fire sprinkler systems that may help. G. Saraduke (personal communication, April, 2001).

As the building regulatory process becomes more complex and technical, the building official must become more knowledgeable and technical. (Moriarty, 1978, p. 381).

Gagnon states components on an automatic sprinkler system must be listed for fire protection service and rated to withstand the maximum pressures anticipated for the system. The minimum pressure rating being 175 pounds per square inch (psi). Sprinklers must be new, be of a temperature rating commensurate with its anticipated environment, and have all required markings as specified in NFPA 13. Steel piping and copper tubing and their associated fittings must meet the standards established by the American Society for the Testing of Materials (ASTM) and the American National Standards Institute (ANSI). Fittings are manufactured in many varieties. Joining methods include threaded, welded, flanged, crimped, drilled hole, cut or rolled grooved, brazed or soldered, pipe bending, and glued for plastic pipe. Hangers supporting sprinkler systems must be capable of holding five times the weight of the piping, fittings and water supported by the hanger. Valves consist of OS&Y, wafer check, grooved check, vertical post indicator, lug style butterfly, wall indicator, and butterfly valve. (Gagnon, 1997, pgs. 81-87).

When sprinkler systems fail to control a fire, generally there are two primary reasons, (1) the water supply was insufficient for the particular hazard or (2) a valve on the supply line was closed. The fire department connection, if there is one, is considered an auxiliary water supply source. (NFPA, 1994, pgs. 146 & 147).

Pressure gauges are installed on the water and air sides of the dry-pipe valve, at the source of air pressure, in each independent pipe from the air supply to the system, and at the exhausters and accelerators. You can identify these gauges and their purpose using the system installer's plans or the manufacturers's literature. The inspection procedures for dry-pipe systems are much like those for wet-pipe systems, except that you will have to evaluate the source of the air pressure and examine the ancillary equipment unique to this type of system. (NFPA Inspection Manual, 1994, p. 151).

From a fire protection standpoint, there really is not much to sprinkler system design. The engineering aspects of the design are, for the most part, all laid out in NFPA 13. Once the hazard classification and water supply are determined, the sprinkler designer simply applies the rules from NFPA 13. What the design of a sprinkler system is really all about is pipe. (Schulte, April, 1999).

NFPA 13 requires that those components critical to system operation during a fire situation be listed. Components that would not adversely affect the system performance if they were to malfunction during a fire are not required to be listed. The use of listed devices and materials greatly increases the likelihood that the system as a whole will perform as intended when it is needed. For example, over 50 different types of test are performed on a sprinkler during the listing process. These include spray pattern distribution test, temperature test, pressure test, and evaluation of the orifice features and operating element. (Puchovsky, 1996, p. 72).

Sprinklers, escutcheon plates, guards and shields, spare sprinklers, aboveground pipe and tube, underground pipe, fittings, couplings and unions, reducers and bushings, hangers, valves, waterflow alarms, waterflow detection devices are all part of the fire sprinkler system or are appliances. (NFPA 13 Fire Sprinkler Code, 1999, pgs. 15 - pgs. 21).

Underground piping, water supply, public main, fire hydrant, fire department connection, (fire pump, gravity tanks, pressure tanks) if needed, OS & Y valve, backflow preventor, OS & Y valve, dry or wet alarm check valve, gages, aboveground piping, riser, feeder main piping, branch lines, sprinklers, inspectors test valve, main drain piping & valve, fire alarm monitoring are also considered as part of the overall fire sprinkler system. (NFA-Fire Protection Systems and Equipment, 1986, pgs. 7-14 - 7-28).

Automatic sprinkler systems consist of a series of nozzle like devices (called sprinklers) arranged so that the system will automatically distribute sufficient quantities of water to either

extinguish a fire or prevent flashover until firefighters arrive. A sprinkler system layout consists of different sizes of pipe. The system starts with a feeder main that originates from a city or private water supply. The feeder main contains a check valve or backflow preventor to prevent sprinkler water from back flowing into the potable water supply. The feeder main also has a pipe to allow the fire department to augment the system through a fire department connection. Risers are vertical sections of pipe that connect to the feeder main. The riser has the system control valve and associated hardware that is used for testing, alarm activation, and maintenance. Risers supply the cross main. The cross main directly serves a number of branch lines on which the sprinklers are installed. The entire system is supported by hangers and clamps and may be pitched to facilitate drainage. Sprinklers discharge water after the release of a cap or plug that is activated by a heat-release element. (IFSTA , April, 2001, pgs. 160 & 161).

Under normal conditions, the discharge of water from an automatic sprinkler is restrained by a cap or valve held tightly against the orifice by a system of levers and links or other releasing devices pressing down on the cap and anchored firmly by struts on the sprinkler. A common fusible-style automatic sprinkler operates when a metal alloy of predetermined melting point fuses. The solders used are alloys of optimum fusibility composed principally of tin, lead, cadmium, and bismuth; all have sharply defined melting points. A second style of operating element utilizes a frangible bulb. The small bulb, usually of glass, contains a liquid which does not completely fill the bulb, leaving a small air bubble trapped in it. As heat expands the liquid, the bubble disappears, the pressure rises substantially, and the bulb shatters, releasing the valve cap. The exact operating temperature is regulated by adjusting the amount of liquid and the size of the bubble when the bulb is sealed. Other styles of thermos-sensitive operating elements employed to provide automatic discharge include bimetallic discs, fusible alloy pellets, and chemical pellets. (Fleming, 1991, pgs. 5-174 & 5-175).

Once the hazard or commodity classification is determined and a sprinkler spacing and piping layout has been proposed in conformance with the requirements of the standard, the system designer can begin a series of calculations to demonstrate that the delivery of a prescribed rate of water application will be accomplished for the maximum number of sprinklers that might be reasonably expected to operate. (Fleming, 1995, p. 4-57).

Automatic sprinklers serve a dual function as both heat detectors and water distribution nozzles. As such, the response of sprinklers can be estimated using the same methods as for the response of heat detectors. The heat absorption rate of a sprinkler spray is expected to depend on the total surface area of the water droplets. (Fleming, 1995, p. 4-67).

There are four basic types of sprinkler systems, (1) wet-pipe system, (2) dry-pipe system, (3) deluge system, and (4) preaction system. Occupancy hazard classification is the most critical aspect of the sprinkler system design process. If the hazard is underestimated, it is possible for fire to overpower the sprinklers. Hazard classification is not an area in which calculation methods are presently in use. The proper classification of hazard requires experienced judgment and familiarity with relevant NFPA standards. (Fleming, 1995, p. 4-57).

The NFPA Inspection Manual also list four types of systems. (see Appendix B for more information).

In a phone conversation with Ken Sutton, a Professional Engineer with Grinnell Fire Protection Systems Company, Sutton said, “There are basically two types of fire sprinkler systems, wet and dry. Everything else is a combination off of those systems.” K. Sutton (personal interview, May, 2002).

There are six major classifications of automatic sprinklers systems defined in NFPA 13, Standard for the Installation of Sprinkler Systems. Wet-pipe systems use closed automatic sprinklers attached to a piping system containing water under pressure at all

times. It is the most common type of system. Dry-pipe systems employ closed automatic sprinklers attached to a piping system which contains air or nitrogen under pressure. They are usually used only in locations that cannot be heated properly. Preaction systems employ closed automatic sprinklers attached to a piping system which contains air, which may or may not be under pressure. When a fire occurs, a fire detecting device, such as a smoke detector or heat detector, activates and causes the water to flow. They are commonly used in areas where there is a danger of serious water damage. Deluge sprinkler systems employ automatic sprinklers which are open at all times. Combined dry-pipe and preaction systems employ essential features of each system and can operate as either system. Special types of systems depart from requirements of NFPA 13 in such areas as special water supplies and reduced pipe sizes. The systems are installed according to the instructions that accompany their listing by a test laboratory. (NFA, Fire Protection Systems and Equipment, 1991, pgs. 7-15-7-19).

The type of systems addressed by NFPA 13 include wet-pipe, dry-pipe, preaction, deluge, combined dry-pipe preaction, antifreeze, circulating closed looped, outside systems for exposure protection, systems used in refrigerated spaces, and systems for commercial-type cooking equipment and ventilation. (see Appendix B, for more information concerning the discussion of the differences between the types of systems).

Wet-pipe sprinkler systems are the simplest and the most common type of sprinkler system in use. In wet systems, the piping contains water at all times and is connected to a water supply so that water discharges immediately from a sprinkler when it activates. Because there are relatively few components associated with a wet-pipe system, it has a higher degree of reliability than other system types. (NFA, Fire Protection Systems

and Equipment, 1991, p.133).

In any treatment of hazards by general groups of occupancy, it must be noted that individual properties differ markedly and that buildings of the same nominal occupancy classification may show widely different individual hazards that should be considered in any determination of water supply. (Solomon, July, 1991, p. 5-168).

For simplicity's sake, occupancies are classified into three basic hazard categories when installation of automatic sprinkler systems are contemplated: light hazard, ordinary hazard, and extra hazard. In addition to these hazard groupings, there are special occupancy conditions that require consideration. Such conditions include high-piled combustibles, a variety of flammable and combustible liquids, combustible dusts, chemicals, aerosols, and explosives. (NFPA Inspection Manual, 1994, p. 145). (see Appendix B for more information concerning the hazard classifications).

NFPA 13 design requirements are intended to provide a minimum application of water to a fire, that should achieve fire control, or the application of water that limits the size of a fire and allows safe occupant egress and structural protection, until the fire services arrives. Fire service response time is usually between 5 and 10 minutes for many areas. An AHJ may consider response time as a factor when evaluating system design criteria for a specific jurisdiction. (Gagnon, 1997, p. 74).

In an interview with Mike Durst, a representative with the National Fire Sprinkler Association, he said there are three main categories that all have the potential to cause problems in fire sprinkler requirements. They are improper design, installation and maintenance. Of these, the most critical is design. If the system's design is wrong from the start, i.e., water supply, density, hazard class, you end up with a false sense of security with the systems installation. Basically, you will have a system that may not

function or control a fire when needed. The improper installation of a system or maintenance of a system can be corrected. Improper design, unless caught in the review process, can be very costly in more ways than one. M. Durst (personal interview, April, 2002).

The issue is whether or not quality control problems with sprinkler installations were merely a result of differing interpretations of NFPA 13 requirements or were actually the result of poor performance by sprinkler contractors. I would like to suggest that the licensed design professional share equally in the responsibility to ensure adequate quality control. This can be accomplished by (1) providing appropriate, code compliant designs, (2) thoroughly reviewing the contractor's submittals for compliance with the design documents (and making corrections where necessary), and (3) providing adequate field supervision of the contractor's activities. Given the fact that state laws specifically mandate that design professionals be involved in the building design, perhaps design professionals are actually more to blame for quality control problems in the sprinkler industry than sprinkler contractors. Quality control in a sprinkler design and installation is important and the engineer-of-record should not delegate the quality control function to either the sprinkler contractor or the enforcing authority. (Schulte, May, 2002, pgs. 10 & 14).

My rejection rate of initial drawing/calculations submittals I reviewed was somewhere between 95 and 99 percent. Other fire protection engineers in the audience involved with reviewing shop drawings and calculations stated that their rejection rates were roughly 80 percent. The rejection rate of knowledgeable sprinkler shop drawing reviewers (due to noncompliance with NFPA 13 requirements) is far too high.

The quality control problems in the sprinkler installation industry are every bit as

important as the problem with the Omega sprinkler, if not more so. (Schulte, March, 2001, p. 16).

When sprinkler systems fail to control a fire, generally there are two primary reasons: the water supply was insufficient for the particular hazard or a valve on the supply line was closed. (NFPA Inspection Manual, 1994, p. 146).

Storage over 12 feet in height, fuel loading, or blockage of the sprinkler head may all be problems that prevent or impeded the sprinklers proper operation, but those are all code compliance issues. Of the remaining fires that were not controlled in sprinkler-equipped buildings, failure was due to improper maintenance, an inadequate or shut off water supply, incorrect design, obstructions, or partial protection. (IFSTA, 2001, p. 159).

Dave Pulley, a local fire maintenance contractor that services and performs sprinkler system testing, said he sees alterations to approved systems by plumbing contractors that take the system out of code compliance, such as adding heads, pipes and fittings with no plans being submitted or reviewed, design shop drawings with no calculations being done, installing or reinstalling the wrong type of sprinkler heads, and installing the wrong temperature rating of replacement heads. D. Pulley (personal interview, May, 2002).

PROCEDURES

The research procedures utilized in this project began with a literature review conducted at the Learning Resource Center (LRC) at the National Fire Academy in March of 2001.

Additional information was gathered and evaluated for the project under the Interlibrary Loan Program (ILL), located at the Laramie County Community College in Cheyenne, Wyoming, and the State Library. The review concentrated on fire trade journals, magazines, the Uniform Building and Fire Code, NFPA Standards, fire protection systems text books, the

National Fire Protection Handbook and the Standard of Fire Protection Engineer's Handbook, and the NFPA Sprinkler System Installation pocket guide.

A literature review of the author's personal library was conducted with a review of applicable state statutes, laws, regulations and codes. Personal interviews with FPE's and FPE Technicians were conducted. Phone interviews with NICET certified systems designers from fire sprinkler companies were conducted, and also interviews with fire marshals from along the front range of Colorado and Wyoming were done, along with their plans examiners. Through the information provided by the field experts and design engineers, and study of the reference materials, a rough fire sprinkler systems checklist and guideline were developed specifically for Cheyenne's Fire and Rescue plans examiner. see appendix A. Definition of Terms

Code. Includes mandatory requirements that are suitable for adoption into law.

CLB. Contractor Licensing Board. **Fire Protection Engineer (FPE).** A person who is qualified by experience and education to perform fire protection systems design, based on principles of physics, chemistry, thermodynamics, static's, dynamics, fluid dynamics, and upper level mathematics. **Fire Protection Engineer Technicians (FPE Tech).** Those persons with the knowledge, skill, and training to perform fire protection layout, using accepted national standards. **Fire Protection System Design.** Based on engineering criteria that may not always coincidewith criteria found in an accepted national standard. **Fire Protection System Layout.**

The act of following the requirements of a standard to execute a drawing.

FPB. Fire Prevention Bureau.

Guide. Informational, but not binding.

Home Rule Authority. Authority delegated by the State for local municipalities to establish rules and regulations concerning code enforcement.

ICBO. International Committee of Building Officials. A certification board for building

tradescode enforcers.

IFSTA. International Fire Service Training Association.

NFA. National Fire Academy.

NFPA. National Fire Protection Association.

NICET. National Institute for Certification of Engineering Technicians.

Practice of Architecture. Rendering or offering to render service to clients, generally, including any one or any combination of the following practices or professional services, advice, consultation, planning, architectural design, drawings and specifications, general administration of the contract as the owner's representative during the construction phase, wherein expert knowledge and skill are required in connection with erection, enlargement or alteration of any building or buildings, or the equipment, or utilities thereof or the accessories thereto, wherein the safeguarding of life, health or property is concerned or involved. **Recommended Practice.** Provides non-mandatory advice. **Standard.** Includes mandatory requirements used by an approving authority.

SFM. State Fire Marshal.

UFC. Uniform Fire Code. Research Methodology

An action research was conducted with the desired outcome being a checklist and guide created to assist the fire safety plans reviewer in the review of fire sprinkler system construction plans.

Assumptions and Limitations

It was assumed that those individuals interviewed did in fact have substantial technical knowledge and background in their respective fields of expertise, those being, engineering, fire science, fire protective systems, code enforcement, and plans review. At this time, it is assumed

that the new civilian plans examiner has at least some knowledge through on the job training conducted to review these systems, and that he and others will be able to benefit from the use of the checklist and guide.

A limitation was the amount of current, if any, resource literature available concerning plan review of fire sprinkler systems.

RESULTS

A checklist and guideline was created for the use of the plans examiner, see appendix A.

Answers to Research Questions

Research Question 1. Wyoming statutes require that all plans for buildings designed to be constructed, under the “architects” section of the state code that are over one story in height, are to be occupied by more than ten people, are commercial buildings, and are not exempt as agricultural in nature are required to be stamped by a Wyoming licensed professional engineer. (Dubay, October 1997). An architect or landscape architect shall affix his seal to all documents, plans or designs he provides. (Wyoming Laws, 1991).

The researcher investigated the Wyoming statutes, and what the legal basis allowing for the enforcement of fire sprinkler system requirements were and found the following: (a) that the Uniform Fire Code (UFC) is adopted by the SFM office pursuant to Wyoming statute, (b) that the SFM is authorized to issue local municipalities, cities and towns “Home Rule Authority”, (c) that Wyoming statutes require the above to follow the “Administrative Procedure Act” in adoption of ordinances, (d) that Cheyenne City Code chapter 17 titled Fire Department, applies to the FPB within the jurisdiction of the City of Cheyenne, (e) that the City is authorized to amend such code by ordinance, to a more stringent status as deemed necessary for the local jurisdiction, (f) that the UFC 1997 edition was adopted in May of 1998 by the City Council, (g)

that article 10 of the UFC 1997 edition applies to fire sprinkler requirements for the various occupancies listed in the code, (h) that Chapter 17 of the City Ordinance references NFPA 13 for the installation of fire sprinkler systems, which in turn references NFPA 170 Symbols for Construction Design, (i) that the Contractor's Licensing Board for the City is appointed by the Mayor and is authorized as such to set rules and regulations for all contractors doing business within the City of Cheyenne, and (j) that all new or delinquent fire sprinkler contractors as of 1998 were required and were administered a written examination on fire sprinkler systems installation by the Licensing Board.

Some may argue that the AHJ should be responsible for quality assurance. Those thinking this way should seriously consider that an error made by a designer or installer of a fire protection system is not absolved of responsibility if an AHJ misses the error. Most governmental AHJ's are immune from civil liability in cases of deaths caused by faulty fire protection systems, whereas designers and contractors are not. (Gagnon, 1997, p. 280).

The use of a checklist during the plans review and the inclusion of all appropriate agencies can also reduce the potential for an oversight. If no design professional is used, the code official has an increased responsibility to conduct a thorough plans review and to monitor the construction. As a result, many code officials require the use of a registered design professional. Case law, for the most part, assigns the responsibility for code compliance to the architect or engineer. (NFA, Plans Review for Inspectors, 1994, p. I-17-I-19).

Research Question 2. In an interview with (FPE) Glen Saraduke, from Golden, Colorado, Mr. Saraduke said that to his knowledge most plans examiners in fire departments in the western states usually are certified by ICBO only in the UFC, and rely on the Building Official's review

for the UBC's portion of the plans review. The plan reviewer should be ICBO Certified as a plans examiner. If the municipalities are conducting joint reviews, there may not be a need for the duplication by the fire department to review for the UBC requirements for fire safety, if you are comfortable with their review process. This certification provides theoretical background in the Uniform Building Code's application for review of construction designs.

Fire safety plans review requires a general background knowledge of blueprint reading ability. The reviewer must possess technical knowledge in the specific fire safety systems being reviewed, along with the ability to analyze the building code and fire codes applications to those systems. He or she should have additional working knowledge and background in the fire code and NFPA standards.

The knowledge, skills, and abilities required to conduct a thorough plans examination, specifically for fire protective systems, is too broad of an area generally speaking for one plans reviewer. This requirement should be spread amongst several individuals in specific technical areas of the codes and standards. The person most versed in the area should review the plans for that system. G. Saraduke (personal communication, June 2001).

On really technical or specialized fire protective systems, the vast majority rely on technical reports and consultation with either a design engineer and/or a FPE. Third party review and acceptance testing usually are not the norm, except on very few jobs and specialty fire protection such as fire proofing of structural systems in high rise construction, where certification and or licensing is required by either the project engineer or the Building Official. A. Baker (personal communication, March 2001).

In a phone conversation with Page Dougherty, ICBOs Fire Protection Specialist, Dougherty was asked what the requirements are for more specific reviews concerning fire protective systems on the plans examination review. Dougherty said, "I'm not aware that there are any

requirements for the ICBO Plans Examiner to have any specialty training to conduct these reviews. I do think they should take specialty seminars or college level courses in the specific fields of fire sprinkler system, fire alarm and others. NFPA offers these as well as the National Sprinkler Association, and Fire Alarm Association. NICET has a certification for technicians in those specific areas. I would suggest you call Bill Hopple for fire alarm training, and Gene Indoff for sprinkler systems. I will tell you this, I think you have a legitimate point concerning the review of construction plans for fire protective systems and ICBO is conducting a staff study in that area, and is considering offering a certification for 'Fire Marshals' that will deal specifically with that, because to the best of my knowledge there isn't any certification offered anywhere. Contact the California State Fire Marshal's Office, they have a great training program for fire prevention for inspectors, plans reviewers, and fire marshals." P. Dougherty (phone interview, August, 2001).

Interviews with Fire Protection Specialist

In a phone conversation with Bill Hopple, with Tyco-Simplex fire alarm company, Bill said, "I offer courses dealing with specific areas of fire alarm systems. Most courses cover the basics on an introductory level and I travel all over presenting these. I'm teaching a specific course for the California State Fire Marshal's Office, (plans check-1013), that covers just what you've been asking about. This course covers the design end of fire alarms and would provide the plans examiner the background to conduct a proper review. I would be willing to set up something similar to what California has for your department or within the State. Remember this will also be helpful on the fire sprinkler plans review portion for monitoring."

Bill Hopple of Tyco-Simplex fire alarm company said, "NICET offers certification for engineering technicians but I do not believe they will certify plans examiners conducting the plans review on fire alarm or fire sprinkler systems, because they are not a technician. I wish

someone would, I think it is over due.” Hopple said to check with the International Brotherhood of Electrical Workers (IBEW) because they offer classes in fire alarm systems, mostly installation, but some plans reading. B. Hopple (phone interview, August, 2001).

In a phone conversation with Gene Indoff, National Fire Sprinkler Association, Director of Codes, Gene said, “We, NFPA, and several technical colleges offer training in fire sprinkler system design and review. However, I don't know of anyone other than NICET or the other national certification outfit that offers certification. We do present a certificate of attendance with our seminars.” G. Indoff (phone interview, August, 2001).

Phone interview with Jodi Weyers, Oklahoma State University, Career Services Office. Weyers said, “All of the graduates have a strong background in fire protective systems. They may not specifically have certification in the specialty areas of fire alarm or fire sprinkler systems, but have taken courses concerning these areas and are able to conduct plans examinations for code compliance on these. All students are qualified at the time of graduation to sit for the general engineering technicians certification offered by NICET. Those that have worked or are working for specialty companies may qualify to test in the specific area for NICET certification but that is not very often.” J.Weyers (phone conversation, May, 2001).

This author did contact the Society of Fire Protection Engineers and found that they have an annual professional development week that covers very specific fire protective systems, in addition to fire alarm and fire sprinkler systems. (SFPE, 2001). Additionally, ICBO offers a number of seminars related to the Building Code and Fire Code. There were a number of courses specifically offered in the area of plans examination for both fire and building, but nothing on specialty systems. (ICBO, 2001).

Gagnon specifies by definition what a fire protective engineer is. The fire protective engineer is qualified by experience and education to perform protective systems design. He further defines

what fire protective system design is. Fire protection technicians are persons with the knowledge, skill, and training to perform fire protection layout, the act of following the requirements of a standard to execute a drawing using accepted national standards. (Gagnon, 1997, p. 17).

According to Gagnon, the NFPA, publishes over 290 codes, standards, recommended practices, and guides that apply to fire safety and the design of fire protection systems. (Gagnon, 1997). He specifically sites NFPA 13 to be used as a minimum in the design of fire sprinkler systems, NFPA 25 for the maintenance of water based fire protective systems, and NFPA 20 for fire pumps and NFPA 24 for private fire service mains.

In an interview with Glen Saraduke, a Fire Protection Engineer (FPE), he said, “Under NICET rules, only a NICET level IV is recognized to perform fire sprinkler system design, however a level III technician can perform layout. The plans examiner should be trained and knowledgeable in plans review, it lends more credibility to the review if this person is ICBO certified as a plans examiner. He should have additional training and knowledge in specific fire specialty systems, such as fire sprinkler systems design, NFPA offers courses on fire sprinkler systems that may help you.” G. Saraduke (personal communication, April, 2001).

Research Question 3. A sprinkler system layout consists of different sizes of pipe. The system starts with a feeder main that originates from a city or private water supply. A detailed water supply survey and test must be conducted to ensure that an adequate water is available for the project. (Gagnon, 1997, p. 45). The feeder main contains a check valve or backflow preventor to prevent sprinkler water from back flowing into the potable water supply. The feeder main also has a pipe to allow the fire department to augment the system through a fire department connection. Risers are vertical sections of pipe that connect to the feeder main. The riser has the system control valve and associated hardware that is used for testing, alarm

activation, and maintenance. Risers supply the cross main. The cross main directly serves a number of branch lines on which the sprinklers are installed. The entire system is supported by hangers and clamps and may be pitched to facilitate drainage. Sprinklers discharge water after the release of a cap or plug that is activated by a heat-release element. (International Fire Service Training Association (IFSTA) April, 2001, pgs. 160 & 161).

Gagnon stated that components on an automatic sprinkler system must be listed for fire protection service and rated to withstand the maximum pressures anticipated for the system. The minimum pressure rating being 175 pounds per square inch (psi). Sprinklers must be new, be of a temperature rating commensurate with its anticipated environment, and have all required markings as specified in NFPA 13. Steel piping and copper tubing and their associated fittings must meet the standards established by the American Society for the Testing of Materials (ASTM) and the American National Standards Institute (ANSI). Fittings are manufactured in many varieties. Joining methods include threaded, welded, flanged, crimped, drilled hole, cut or rolled grooved, brazed or soldered, pipe bending, and glued for plastic pipe. Hangers supporting sprinkler systems must be capable of holding five times the weight of the piping, fittings and water supported by the hangar. Valves consist of OS&Y, wafer check, grooved check, vertical post indicator, lug style butterfly, wall indicator, and butterfly valve. (Gagnon, 1997, pgs. 81-87).

When sprinkler systems fail to control a fire, generally there are two primary reasons: the water supply was insufficient for the particular hazard or a valve on the supply line was closed. The fire department connection, if there is one, is considered an auxiliary water supply source. (NFPA, Inspection Manual, 1994, pgs. 146 & 147).

NFPA 13 requires that those components critical to system operation during a fire situation be listed. Components that would not adversely affect the system performance if they were to

malfunction during a fire are not required to be listed. The use of listed devices and materials greatly increases the likelihood that the system as a whole will perform as intended when it is needed. For example, over 50 different types of test are performed on a sprinkler during the listing process. These include spray pattern distribution test, temperature test, pressure test, and evaluation of the orifice features and operating element. (Puchovsky, 1996, p. 72).

Once the hazard or commodity classification is determined and a sprinkler spacing and piping layout has been proposed in conformance with the requirements of the standard, the system designer can begin a series of calculations to demonstrate that the delivery of a prescribed rate of water application will be accomplished for the maximum number of sprinklers that might be reasonably expected to operate. (Fleming, SFPE Handbook of Fire Protection Engineering, 1995, p. 4-57).

Automatic sprinklers serve a dual function as both heat detectors and water distribution nozzles. As such, the response of sprinklers can be estimated using the same methods as for the response of heat detectors. The heat absorption rate of a sprinkler spray is expected to depend on the total surface area of the water droplets. (Fleming, SFPE Handbook of Fire Protection Engineering, 1995, p. 4-67).

Underground piping, water supply, public main, fire hydrant, fire department connection (fire pump, gravity tanks, pressure tanks) if needed, OS & Y valve, backflow preventor, OS & Y valve, dry or wet alarm check valve, gauges, aboveground piping, riser, feeder main piping, branch lines, sprinklers, inspectors test valve, main drain piping & valve, fire alarm monitoring are also considered as part of the overall fire sprinkler system. (NFA, Fire Protection Systems and Equipment, 1986, pgs. 7-14 - 7-28).

Research Question 4. A detailed water supply survey and test must be conducted to ensure that adequate water is available for the project. (Gagnon, 1997, p. 45). According to Gagnon, a

determination must first be made concerning whether the fire sprinkler system is to be installed in a new building or in an existing structure. If it is an existing building, a site survey may need to be done to establish a structural plan. In new construction, the structural plan is already established. Walls can then be measured using column center lines as a point of reference. Identify any concealed spaces or small inaccessible enclosures where sprinkler protection is not provided. (Note it is important to identify if these spaces contain combustibles or items of combustible construction). (Gagnon, 1997, p. 38). The next step is to develop a system design strategy. Determine the most logical system arrangement (gridded, looped or tree systems) and develop understanding of probable sprinkler main locations, line arrangement, and direction and riser location. The establishment of a survey reference elevation from which all other elevations are measured is the next step. Note this should be the lowest, flattest, most reliable elevation that can be found. Measure all floor to floor elevations, noting any potential mechanical or structural conflicts during this phase. At this point, the layout of the building and the fire protective system is started back at the design office. (Gagnon, 1997, p. 40). The systems hydraulic calculation is then conducted, utilizing the following steps: (1) selecting occupancy, (2) selecting a hydraulic density, (3) determining the length of the hydraulically most demanding area, (4) determining the number of sprinklers flowing along the length of the design area, (5) determining the configuration of sprinklers in the hydraulically most demanding area, (6) determining the minimum flow at the hydraulically most demanding sprinkler, (7) determining the minimum pressure at the hydraulically most demanding sprinkler, and (8) determining friction loss in each pipe segment.

Research Question 5. In an interview with Mike Durst, a representative with the National Fire Sprinkler Association, he said there are three main categories that all have the potential to cause problems in fire sprinkler requirements. They are improper

design, installation and maintenance. Of these, the most critical is design. If the system's design is wrong from the start, i.e., water supply, density, and hazard class, you end up with a false sense of security with the system's installation. Basically, you will have a system that may not function or control a fire when needed. The improper installation of a system or maintenance of a system can be corrected. Improper design, unless caught in the review process, can be very costly in more ways than one. M. Durst (personal interview, April, 2002).

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Remmer discusses the problems of building regulatory agencies in facing rapid advances in the technology and scope of building regulation and the implied increase in volume of work (Remmer, 1978, p. 359). One of the results of this burgeoning technology and awareness is the recognition that regulatory agencies, limited in both staff and expertise, must make decisions, either explicitly or tacitly, on allocations of its limited resources.

An advantage of performance-based codes is that they will permit the incorporation and use of the latest building and fire research, data and models. These models will be used as the tools for measuring the performance of any number of design alternatives against the established safety levels. (Haviland, 1978). (Hadjisophocleous, Benichou, Tamim, 1998, p. 12). Sanderson presented a brief historical development of the building codes, a definition of specification and performance codes, stating that the model codes consisted of both specification and performance requirements. He also indicated that many code requirements were based on experience rather than scientific facts. (Sanderson, December, 1969).

Haviland identified a number of problems with the existing codes, including non-uniform fire safety levels in buildings, confusion between code objectives and methods of achieving them, little recognition of the wide variations in real hazard within a given occupancy, lack of fire safety, difficulty in the interpretation of the language, and complexity in finding and handling all the applicable code requirements. (Haviland, 1978). (Hadjisophocleous, Benichou, Tamim, p. 12, 1998).

There is a need to update the codes to include performance measures to take advantage of new technologies, materials and methods. The author detailed the fire safety provisions in the model building codes and provided the first outline of the fire safety objectives of building codes. He reported on the use of standards as code references and indicated three types of standards, (1) materials standards, (2) engineering practice standards for basic design procedures, and (3) testing standard. (Boring, Spence, Wells, 1981).

Wakamatsu outlined a design method for evaluating building fire safety by substituting the prescriptive code requirements with equivalency. These were evaluated based on the performance of three sub-systems, (1) fire outbreak and spread, (2) smoke control and evacuation, and (3) fire resistance. (Wakamatsu, 1988).

Corbett investigated the issues related to codes relying on integration of fire safety design methods in the design of buildings. Prescriptive requirements are easy to understand and enforce, they provide for alternative solutions, although such solutions are not used very often because code officials are reluctant to use them. He proposed development of a single fire and building code and establishment of specific minimum levels of fire safety or objectives to be achieved. (Corbett, 1991).

In 1991, DiNenno reported that the major reasons for not implementing performance based fire safety building design were the lack of measurable fire safety objectives, calculation uncertainty, gaps in the existing technical knowledge, and the difficulty in quantifying. (DiNenno, 1991).

Bukowski and Tanaka listed disadvantages of the prescriptive codes as providing only one way of achieving the desired level of safety. They proposed establishing fire safety goals based on community characteristics. Their framework for evaluation procedures should consider three key elements, (1) standard fire conditions and design fires (fire scenarios), (2) standard safety criteria, and (3) standard safety factors to account for uncertainties in the calculations. (Bukowski, Tanaka, 1992).

Performance goals should specify a level of safety that is independent of the prescriptive code requirements. These requirements were divided into four categories, (1) outbreak of fire, (2) means of escape, (3) spread of fire, and (4) structural stability during fire. Buchanan also developed a guide for quantifying, which allowed the application of fire engineering to the code evaluation and review process. (Buchanan, 1994).

In their review of the technical and philosophical aspects of performance based codes, Bukowski and Babrauskas enumerated that the codes should not be complex, but be clear enough to know the expected primary safety features, allow for verification of the plans, calculations and

specifications providing these primary safety features, and have no need for a large computer program to evaluate performance. They referenced ISO/TC92/SC4, fire safety goals that extract three basic societal objectives, (1) to limit the spread of fire and smoke, (2) to provide for successful evacuation of occupants, and (3) to provide for effective fire-fighting and rescue operations. (Bukowski, Babrauskas, 1994).

The Canadian Commission on Building and Fire Codes (CCBFC), stated concerns with the performance approach with the requirements for higher technical knowledge on the part of the regulator.

Meacham, with the Society of Fire Protection Engineers (SFPE), concluded that in addition to the technological development of performance codes and fire safety engineering methodologies, there was still a need for education for fire engineers and enforcers to understand the methodologies as well as to gain society's acceptance for the new approach. (Meacham, 1995).

Although prescriptive codes have the advantage that designers can do a design by just following prescriptions and that the code officials can easily determine whether a design follows code requirements, they have many problems. The move from prescriptive to performance based codes is more than just technological advancement and the success of this move will depend on the availability of calculation systems to support the user in trying to meet code objectives and the availability of training programs to educate the user on how to apply these systems. (Benichou, Hadjisophocleous, Tamim, 1998).

Unexpected Findings

The researcher discovered that he had not identified all parties or factors that may have had an influence on the desired change. I was pleasantly surprised to hear that ICBO is considering a certification for the Fire Marshal's position. I was not aware that NICET would not certify the

plans examiners, even at the lower levels of I or II in fire sprinkler engineering technology. The author discovered requirements concerning fire sprinkler design and installation that he was not aware of.

The researcher discovered a case law that establishes the architect or engineer as the responsible party for design of the system even if the plan is reviewed and requirements are missed unintentionally on the review. This holds true only if the plans are required to be engineer stamped.

DISCUSSION

The fire sprinkler checklist and guideline that was developed is specific to the Cheyenne Fire and Rescue. Some of the sprinkler code requirements were modified to fit specific requirements for the City of Cheyenne's jurisdiction. I was surprised that almost every fire prevention bureau cited the fact that they do not utilize a checklist or guide to review their plans. It would be beneficial to have a FPE technician conduct our plans reviews as buildings are becoming more technical in nature and design, as well as the size of the projects.

Because the NFPA 13 fire sprinkler code is utilized, as the design guide, all individuals and research literature pointed to that document as the method to establish the checklist. It is my belief that design, review, installation and maintenance of the fire sprinkler system are all essential to a reliable system. The most critical element is the design and system's layout. During the plans review process is the first opportunity that the fire department has to influence the outcome of the systems design. At this time, we have the responsibility to serve as a check and balance in the construction process for the engineer/designer.

With stricter licensing rules, competent installers are the next most critical element. Ensuring that competent fire sprinkler contractors are the ones to install and maintain this system is critical. Most plumbing contractors and their personnel are not qualified to engage in this line

of work, no matter how closely they believe the two trades are. The fact is, that most fire department plans reviewers and inspectors conducting the review and witness/acceptance testing of the sprinkler systems do not fully know or understand NFPA 13 as well as they should.

The development of the fire sprinkler checklist and guide should standardize Cheyenne's review of fire sprinkler systems. An evaluation of its use and further monitoring of the process will be conducted and adjustments made accordingly. A review of the checklist and guide should be made, after attendance of the National Fire Sprinkler Associations class on plans review is conducted in September of 2002. We will continue to work hard to establish a solid foundation of allowing only qualified and competent people that are designing, reviewing plans and that are allowed to install and maintain fire sprinkler systems in our jurisdiction through rules and regulations, code enforcement, and most of all training of our staff.

Through the interviews with the technical experts in the field of fire sprinkler design, installation and maintenance, a general consensus prevailed as follows: NFPA 13 is the sole source guide to utilize in the design and installation of fire sprinkler systems, the maintenance guide is NFPA 25. A checklist should be developed by each individual plans reviewer to use in the review process. The plans examiner must have the technical knowledge, skills and ability to conduct a proper review. The plans reviewer should take formal training courses specifically covering fire sprinkler systems, design and review that are available through NFPA, trade colleges, and also the National Fire Sprinkler Association. Some fire sprinkler contractors may be willing to provide training to the fire department plans examiner and inspectors.

The reviewer must possess technical knowledge in the specific fire safety systems being reviewed, with the ability to analyze the building code and fire codes applications to those systems. He or she should have additional working knowledge and background in the fire code and NFPA standards. G. Saraduke (personal communication, June 2001).

In a phone conversation with Gene Indoff, National Fire Sprinkler Association, Director of Codes, Gene said, “We, NFPA, and several technical colleges offer training in fire sprinkler system design and review. However, I don't know of anyone other than NICET or the other national certification outfit that offers certification. We do present a certificate of attendance with our seminars.” G. Indoff (phone interview, August, 2001).

Gagnon specifies, by definition, what a fire protective engineer is. Fire protective engineers are qualified by experience and education to perform protective systems design. He further defines what fire protective system design is. Fire protection technicians are persons with the knowledge, skill, and training to perform fire protection layout, the act of following the requirements of a standard to execute a drawing using accepted national standards. (Gagnon, 1997, p. 17).

According to Gagnon, the NFPA publishes over 290 codes, standards, recommended practices, and guides that apply to fire safety and the design of fire protection systems. (Gagnon, 1997).

He specifically sites NFPA 13 to be used as a minimum in the design of fire sprinkler systems, NFPA 25 for the maintenance of water based fire protective systems, and NFPA 20 for fire pumps and NFPA 24 for private fire service mains.

Quality control in a sprinkler design and installation is important and the engineer-of-record should not delegate the quality control function to either the sprinkler contractor or the enforcing authority. (Schulte, May, 2002, pgs. 10 &14).

The use of a checklist during the plans review and the inclusion of all appropriate agencies can also reduce the potential for an oversight. If no design professional is used, the code official has an increased responsibility to conduct a thorough plans review and to monitor the construction. As a result, many code officials require the use of a registered design professional.

Case law, for the most part, assigns the responsibility for code compliance to the architect or engineer. (NFA, Plans Review for Inspectors, 1994, p. I-17-I-19).

Meacham, with the Society of Fire Protection Engineers (SFPE), concluded that in addition to the technological development of performance codes and fire safety engineering methodologies, there was still a need for education for fire engineers and enforcers to understand the methodologies as well as to gain society's acceptance for the new approach. (Meacham, 1995).

RECOMMENDATIONS

The Cheyenne Fire and Rescue should implement and evaluate the checklist and guideline for a year. The checklist and guideline should provide some guidance of what the requirements are, show the legal flow for authority, and give the reviewers an idea of where to find answers to questions they may have. I would recommend that the checklist and guide be used by the reviewers, that they develop their own checklist and guide once they become familiar with the process of conducting fire sprinkler plan reviews.

Specialty training classes in fire sprinkler systems plan review and testing requirements should be required and provided to all fire prevention inspectors and plans reviewers. Arrangements have been made with the National Fire Sprinkler Association to conduct a fire sprinkler design course for a plans examiner's course in September of 2002, and they will provide three slots free to the department for hosting this course. The civilian plans examiner should be required to become ICBO certified as a "Plans Examiner" as soon as possible.

If the plans examiner's position becomes open in the future, a certified fire protection engineer should be hired, preferably one with background in the review and acceptance testing of all fire protective systems, including fire sprinkler systems.

Legal research needs to be done concerning the requirement for a Wyoming licensed

engineer's stamp on all plans that are submitted for review. The question arises from the confusion of whether pre-engineered layout performed by a NICET certified engineering technician constitutes design or if this is considered layout as Gagnon indicates in his book.

It is recommended that each fire department conduct research on a state by state basis and within each jurisdiction to know where their legal authority comes from to conduct fire protective systems plans reviews and the scope of their authority and responsibilities.

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APPENDIX A

Fire Sprinkler Plan Check List



AND GUIDE FOR PLANS REVIEWERS

Project:

Project No.

Project & Drawing Review Sheet

Engineering Technician:

Review By:

Date:

The best prerequisite for plan review is familiarity with the NFPA 13 Standards. Knowledgeable mechanical engineers who are trained in fire sprinkler design and/or layout are hard to find, especially in Cheyenne Wyoming. Even those individuals who may have some experience or background in either the fire department or insurance business may not be capable of determining the requirements of NFPA 13, the Fire Sprinkler Code.

While it does no good to review an incomplete fire sprinkler plan, there are those who do just that. They are more interested in the review fee than being concerned with the code's requirements and ensuring that a reliable sprinkler system has been installed. Reviewing a shop drawing that is a preliminary draft or not complete does no good. There are enough field piping changes that are made by installers, that alter the presupposed hydraulic performance of the system. They do not reflect the piping configuration of the final system's installation and are a useless exercise, **do not review incomplete plans that are submitted.** The FPB's policy has been not to review sprinkler plans and calculations which are obviously lacking in design.

A letter of rejection will be sent to the submitter, advising that the plan's design does not warrant review and will require that professional assistance be obtained before resubmittal. The reviewer must first decide whether or not a review will be of value depending on the plans quality.

The following statement shall be placed on all incomplete plans that are reviewed: "The

following corrections in plans review are required” list what they are, and “This correction sheet must be returned with Corrected Plans.”

The reviewer’s job must not turn into one of educating the designer nor that of turning the process into one in which the reviewer is actually doing the system’s design. His comments should be concerned with the overall project of sprinkler design and installation. The majority of fire sprinkler plan reviews are completed by local fire departments, engineering firms, insurance companies, and building officials. An ability to scrutinize drawings intelligently is required for these tasks, having knowledge of hydraulic principles is a must.

The reviewer who possesses experience in preparing shop drawings and hydraulic calculations, has an advantage because he may know exactly what the designer had in mind and what the designer’s proficiency level is.

The process involves checking the entire plan for any possible errors, lack of complete sprinkler coverage, or omissions of key plan components. Utilizing a checklist/guide is the best way for a plan reviewer to conduct the review. Because fire codes are becoming more complex in nature, and the fact that there have been so many advances in the types of fire protection equipment, there has been a growing dissatisfaction in the fire protection community of who should actually conduct the fire sprinkler reviews. This requires that the reviewer possess a broader knowledge and understanding of the trade of fire sprinkler design, installation and maintenance.

By putting a seal on engineered drawings, a professional engineer is accepting responsibility and liability for system design of fire protection systems. If a qualified fire protection engineer is not involved, and the plans are not stamped, the city may be left with that potential liability. However, the fact is that the automatic sprinkler contractor is responsible for the fire sprinkler system’s integrity. He is ultimately responsible for its design and future performance.

The checklist contains only basic details and should never be considered as assuring that the review has been completed. No list of items on a checklist could ever be that complete. The reviewers should generate their own checklists, once familiar and comfortable with the review process. It should include reminders to check head spacing, inspector’s test location, water supply information, conditions regarding the fire department connection, location of structural members, combustible concealed spaces, occupancy characteristics, flushing connections, hangers, underground mains, alarms (verify connection to an approved central station), hydraulic calculations, pitched roofs, and so on.

Sprinkler head data sheets must be submitted because they affect the critical review particulars of sprinkler spacing, location, and position. The checklists may be long, and may contain certain non-applicable categories, mark those NA, concentrate on code compliance and hydraulic adequacy. The plan reviewer needs to check that all areas of the building are properly sprinklered, while ensuring that the hydraulic calculations prove out system adequacy. On certain projects, the hydraulic adequacy is fairly apparent due to either high available water pressure and volume, smaller system size; the light hazard and low elevation,

or all of the above. If in the (contractor's) interests of trimming system pipe size, a typical job may be hydraulically designed to conform to the available water supply, by placing a system demand point on the hydraulic graph paper that is very close to the water supply curve, this should raise a red-flag. Designers generally like to leave a safety cushion of about 5 psi on their finished calculations. But if the required densities are high, the available pressure moderate, no pump is used, and the building is tall, then you know that the designer had to struggle. These are projects where submitted calculations show a design point very close to the curve, sometimes with a safety cushion of less than 1 psi. Watch these reviews!

System additions are often a hydraulic challenge in system design constraints for the designer, because of the necessity for using the existing piping as part of the supply. These are the type of projects where it becomes necessary to examine the calculations very closely. Time should be taken for the reviewer to calculate the system himself. If the calculations checked out, it was an easy way to verify the system's reliability. Then you can simply run your usual checks on the designer's submitted program sheets.

The following list, itemizes the information that shall appear on all working plans/shop drawings for Cheyenne's FPB. The list is taken from NFPA 13. Standard for the Installation of Sprinkler Systems. 1999 edition. Reference chapter 8, Plans and Calculations.

WORKING PLANS

1. Name of owner and occupant.
2. Location, including street address.
3. Point of compass.
4. Full-height cross section, or schematic diagram, including structural member information if required for clarity and including ceiling construction and method of protection for metallic piping.
5. Location of partitions.
6. Location of fire walls.
7. Occupancy class of each area or room.
8. Location and size of concealed spaces, closets, attics, and bathrooms.
9. Any small enclosures in which no sprinklers are to be installed.
10. Size of city main in street and whether dead end or circulating if dead end, direction and distance the nearest circulating main; and city main test results and system elevation relative to test hydrant.
11. Other sources of water supply, with pressure or elevation.
12. Make, type, model, and nominal K-factor of sprinklers.
13. Temperature rating and location of high-temperature sprinklers.
14. Total area protected by each system on each floor.
15. Number of sprinklers on each riser per floor.
16. Total number of sprinklers on each dry-pipe system, preaction system, combined dry-pipe preaction system, or deluge system.
17. Approximate capacity in gallons of each dry-pipe system.
18. Pipe type and schedule of wall thickness.
19. Nominal pipe size and cutting lengths of pipe (or center-to-center dimensions). Where typical branch lines prevail, it shall be necessary to size only one typical line.

20. Location and size of riser nipples.
21. Type of fitting, joints and location of all welds and bends. The contractor shall specify on drawing any sections to be shop welded, the type of fitting or formations to be used.
22. Type and locations of hangers, sleeves, braces, and methods of securing sprinklers when applicable.
23. All control valves, check valves, drain pipes, and test connections.
24. Make, type, model, and size of alarm or dry-pipe valve.
25. Make, type, model, and size of preaction or deluge valve.
26. Kind and location of alarm bells.
27. Size and location of standpipe risers, hose outlets, hand hose, monitor nozzles, and related equipment.
28. Private fire service main sizes, lengths, locations, weights, materials, point of connection to city main; the sizes, types, and locations of valves, valve indicators, regulators, meters, and valve pits; and the depth that the top of the pipe is laid below grade.
29. Piping provisions for flushing.
30. Where the equipment is to be installed as an addition to an existing system, enough of the existing system indicated on the plans to make all conditions clear.
31. For hydraulically designed systems, the information on the hydraulic data nameplate.
32. A graphic representation of the scale used on all plans.
33. Name and address of contractor.
34. Hydraulic reference points shown on the plan that correspond with comparable reference points on the hydraulic calculation sheets.
35. The minimum rate of water application (density), the design area of water application, in-rack sprinkler demand, and the water required for hose streams both inside and outside.
36. The total quantity of water and the pressure required noted at a common reference point for each system.
37. Relative elevations of sprinklers, junction points, and supply or reference points.
38. If room design method is used, all unprotected wall openings throughout the floor protected.
39. Calculation of loads for sizing and details of sway bracing.
40. The setting for pressure-reducing valves.
41. Information about backflow preventors (manufacturer, size, type).
42. Information about antifreeze solution used (type and amount).
43. Size and location of hydrants, showing size and number of outlets and if outlets are to be equipped with independent gate valves. Whether hose houses and equipment are to be provided, and by whom, shall be indicated. Static and residual hydrants that were used in flow tests shall be shown.
44. Size, location, and piping arrangement of fire department connections.
45. Manufacturer's installation instructions for any specially listed equipment, including descriptions, applications, and limitations for any sprinklers, devices, piping, or fittings.
46. Water supply capacity information.
 - a. Location and elevation of static and residual test gauge with relation to the riser reference point.
 - b. Flow location.
 - c. Static pressure, psi (bar).
 - d. Residual pressure, psi (bar).

- e. Flow, gpm (1/min).
- f. Date.
- g. Time.
- h. Test conducted by or information supplied by.
- i. Other sources of water supply, with pressure or elevation.

FIRE PROTECTION DRAWINGS WATER SUPPLY AND DISTRIBUTION SYMBOLS

The drawings in Tables VIII.1 through VII1.12, which are standardized symbols that should be used on all working plans for fire protection systems, are taken from NFPA 170. Fire Safety Symbols. 1999 edition. (Hague, 2001, pgs. 373-380).

Tables not shown due to file size

Tables not shown due to file size

Tables not shown due to file size

Check each dot in each section that is applicable. Note those not marked and ask questions as appropriate!

Plot or Site Plan

- o Areas sprinkled clearly outlined or structure noted as totally sprinkled.
- o North Arrow present and indicating correct direction (plan and/or true-north).
- o Location(s) of city mains indicated as well as size and type of pipe.
- o Direction (if known) of supply or is main looped. Refer to city waterline maps, provided by BOPU.
- o Significant changes in grade elevations indicated.
- o Elevation of finished floor indicated.
- o Vicinity map indicating neighboring streets.
- o Public and private fire hydrants indicated. Static and residual hydrants noted.
- o Flow test data on drawing indicating. Static, Residual, Flow, Date, Time, Witnesses.
- o City sectional control valves indicated. Refer to BOPU's city waterline maps.
- o Proper use of sectional controls on new construction per NFPA 24 or insurance.
- o Location and configuration of concrete thrust blocks indicated. Approx. cubic yards indicated.
- o System riser and lead-in location indicated centerline to outside face of wall.
- o Lead-in detail shown.
- o Plan and Profile provided where required or applicable.
- o Fire Alarm Horn/Strobe indicated over the Fire Department Connection (FDC) locations indicated.
- o Drawing scale clearly indicated per NFPA requirements.
- o Actual street address for project given, not cross streets.
- o Details of fire hydrants, taps, valves, pits clearly indicated and appropriate for city.
- o Bill of materials list provided.
- o Plans prepared by or checked and stamped by a licensed professional engineer as required by the Fire Marshal or project architect/engineer.
- o PIV only required when systems riser OSY valve located in a basement.

Fire Sprinkler Plan General Items and Information

- o Typical general notes and disclaimers on drawings.
- o Miscellaneous foreman notes and/or fabrication instructions shown.
- o Pipe types and schedules consistent with the specifications and estimate guideline.
- o Pipe types and schedules consistent with hydraulic calculations.
- o Materials submitted foreign or domestic per specification and estimate guideline.
- o Trapeze hangers detailed, locations clearly indicated, and all parts listed.
- o Typical drop and/or sprig lengths indicated and quantities shown.
- o System Type (wet, dry, pre-action, etc.) clearly indicated.
- o Boundaries between systems and system types clearly indicated.
- o Final plot is readable. No cluttered text and piping is clearly distinct from architectural background items.
- o Layers not essential for installation, i.e. plumbing &/or cabinet fixtures removed or turned off.

- o Job name and number is in title block.
- o Scale indicated and graphic on drawing.
- o Cross section shown and building type and construction indicated.
- o Riser or connection detail shown.
- o Ceiling heights and room numbers shown.
- o Key plan and match lines provided for projects spanning several sheets.

Fire Sprinkler Head Types, Spacing, and Location

- o No sprinklers farther than one half the maximum allowable spacing except for the 9 foot rule where it applies.
- o Clear spray around columns, over walls and partitions as well as under ducts, soffits or other obstructions.
- o No heads less than 6 feet apart or per listing (ESFR, Large Droplet).
- o Spacing between lines not over 12' or 12'-6" for 25' bays in warehouses or storage areas classified as High Piled.
- o Deflector distances from deck or obstructions per code and/or sprinkler listing.
Distances to joists or beams measured to close edge not centerline.
- o Head spacing does not exceed code and/or manufacturer listing.
- o Areas of sprinkler coverage per code and/or manufacturer listing.
- o Spacing and orifice sizes (K factors) match hydraulic calculations.
- o Sufficient heads included in remote area (check flow and area of coverage).

Branch Lines and Riser Nipples

- o Typical lines noted and/or numbered as typical.
- o Lines clearly indicated as to system by number and color code.
- o Sizes, fittings, lengths, pipe types and schedules match hydraulic calculations.
- o All hangers cut.
- o Hanger spacing and location per code, specification, listing requirements.
- o Appropriate hangers and fasteners for structure used.
- o Pipe lengths beyond last hanger meet code.
- o Changes in elevation up, down, or sloped indicated.
- o Joining method (threaded, grooved, press fit) clearly indicated.
- o Pipe end treatments indicated (G/G, T/G, T/T, etc.).
- o Correct size, type, and location of welded outlets listed.
- o Branch line locations dimensioned to structure not to architectural walls.
- o Center line to Top of Sprinkler and FF (finished floor) clearly indicated.
- o Pipe lengths noted on drawing are final actual cut lengths.
- o All riser nipples have size, length, and direction (up or down) indicated.
- o Riser nipple sizes and lengths match hydraulic calculations.
- o Hydraulic nodes at top and bottom of riser nipples.
- o Riser nipples numbered, listed with lines, and/or noted as typical.

Mains

- o All main piping tagged, numbered and matches stock list.
- o Main piping size and schedule matches hydraulic calculations.

- o All main piping cut, appropriate takeouts used.
- o Welded outlet dimensions add up to main length.
- o Mains dimensioned to structural walls and/or columns.
- o Main elevation noted centerline to Top of Sprinkler and/or finished floor.
- o Main hangers spaced per code and specification.
- o Where trapeze hangers are used, standard hangers used at intermediate structural beams or trusses.
- o Typical pieces noted and listed as typical.
- o Pipe end treatments indicated (G/G, T/G, T/T, etc.).
- o Size and location of reducing couplings indicated.
- o Main piping color coded where helpful or necessary.
- o Seismic bracing provided and properly located where required by code.
- o Correct size, type, and location of welded outlets, fittings, or flanges listed.

Coordination Efforts

- o Duct work. Roof Top Unit (RTL) locations and roof or ceiling penetrations indicated.
- o Structural steel located and top of steel (TOS) elevations noted compared to finished floor elevation.
- o Structural member types and sizes shown (i.e., W14).
- o Changes in structure type, height, direction clearly noted.
- o Heads located in structural steel obey spacing and location rules for type of sprinkler
 - ESFR and Large Drop sprinklers are located minimum or farther from edge of obstruction, not centerline.
- o Location of roof drains and/or other significant piping shown and/or accounted for.
- o Ceiling grid locations confirmed and tied to known structural point (i.e., column lines).
- o Light locations indicated including recessed and/or canister types.
- o Depth of recessed light fixtures verified (can be as little as 4" and as much as 10").
- o Plumbing piping and roof vent locations avoided.
- o Large conduit and/or cable trays indicated and/or avoided (elevations shown where critical).
- o Written verification of various agreements as to location, elevation and timing to parties involved.
- o The sprinkler contractor provided with notes, information concerning coordination efforts and agreements.

Riser and/or Connection Detail

- o Type of control valve indicated (OS&Y, butterfly, etc.).
- o Alarm valve, if used, noted including indication with or without retard chamber and/or water motor gong. Note. Cheyenne's Fire Marshal requires horn/strobe over FDC.
- o All riser pipes sized and cut lengths noted.
- o Additional check valves and type indicated (wafer, swing, grooved, etc.).
- o Outlet provided (or tee) for Fire Department Connection.
- o Flow switch indicated, including type.
- o Tamper switch indicated, if required. Type appropriate for control valve. Indication if electronically monitored. Signs required as necessary for ceiling areas.

- o Additional pipe and fittings included for main drain, bell line and bell drain.
- o Fire Department Connection, if on riser, shown.
- o Riser located sufficient distance from wall to permit NRS gate valve if WPI used..
- o If WPI to be used, all parts provided for assembly.
- o Flanged connections indicate size and equipment required.

Fire Department Connection (FDC)

- o A fire hydrant is required by Cheyenne FPB rules to be within 100 ft. of the FDC.
- o Size of FDC indicated and per code, both inlets and outlets.
- o Number of inlets sufficient to satisfy code. (approx. 250 gpm per 2½ inlet).
- o The type of fire department threads noted.
- o Finish noted (brass, polished, etc.).
- o Wall plate included with appropriate lettering (and finish).
- o Break caps or matching plugs with chains provided (with correct finish).
- o Ball drip included where necessary or required. (not necessary for a single clapper FDC).
- o Pipe through wall galvanized.
- o FDC located at correct and/or acceptable height above grade. Not less than 36 inches from grade.
- o Double Check/Backflow Preventor valve provided including appropriate fittings.
- o Minimum of 4 feet of pipe from check to inside of wall in areas subject to freezing.
- o Check valve below main control and FDC if dry system.
- o FDC located below (supply side) of main control valves on multiple riser manifold.

Hydraulic Calculations (see procedure for manual calculations by Brian Harris and Melly's 7-step process).

- o Correct density and remote area size for expected hazard.
- o System demand plus hose is as expected given density, remote area, and hazard.
- o End head, starting pressure per code and sprinkler head listing.
- o All changes in elevation accounted for, including slope of pipe on dry systems.
- o Width of remote area according to code and/or insurance requirements (1.2 or 1.4 rule).
- o Remote area includes sufficient number of heads.
- o Remote area reduction taken, where permitted, for fast response heads.
- o Sprinkler K. factors appropriate and match drawing.
- o Hydraulic nodes on the drawings.
- o Remote area clearly identified.
- o Remote area shifts indicated for arid calculations.
- o Correct inside diameter indicated for type of pipe chosen.
- o C factor appropriate for type of pipe and/or system.
- o Remote area increased 30% for dry system.
- o Proper fittings indicated at changes in pipe direction and/or size.
- o Fitting equivalent lengths per code.
- o Equivalent length included for grooves where required.
- o Hose demand included inside/outside per code.
- o Pipe lengths match those on drawings.
- o Appropriate loss for backflow prevention device(s) included.

- o Calculation summary included on drawing.
- o Hydraulic placards for each system riser filled out.
- o Final calculation print outs include: cover sheet, nl. 85 graph, and complete calculation printout.
- o System number and remote area location clearly indicated on all sets of calculations.
- o Sufficient safety factor allowed, 5 psi or 10% below the available supply as a general rule.

Dry-pipe Systems

- o Hydraulic area increased by 30%.
- o Capacity of system noted, appropriate compressor chosen.
- o Compressor and/or air maintenance device provided.
- o Accelerators and/or exhausters provided where necessary.
- o Pendant sprinklers are dry pendant type or on return bends (goose necks) in heated areas.
- o C=100 in hydraulic calculations.
- o Listed gaskets and couplings for dry system used.
- o Used grooved reducers unless groove reducing couplings listed for dry system use.
- o Drum drips provided for low points, auxiliary drains.
- o The valve room is heated, lighted and full-time power provided to air compressor.
- o Mains and branch lines sloped for drain according to code.
- o Hanger and riser nipple lengths account for slope of roof as well as slope of pipe required by NFPA.
- o Fire Dept. Connection located below the dry-pipe valve and above main control valve, unless equipment listed otherwise (Victaulic).
- o Galvanized pipe used where required code.
- o Correct C factor used for galvanized pipe.
- o Correct compressor, air dryers, and piping used for extremely cold freezer. Consider nitrogen vs. dry air configurations.

Pre-Action Systems

- o Non-Interlocked.
- o Single Interlocked.
- o Double Interlocked.
- o Low Pressure.
- o High Pressure.
- o System capacity per code.
- o Additional check valve in riser when required by manufacturer, code.
- o Listed materials and gaskets used.
- o Compressor and/or air maintenance device if required.
- o Appropriate release panel for equipment (or listed with) provided.
- o Interface with detection system provided (alarm panel to release panel).
- o Low air alarm provided where necessary or required .

Deluge Systems

Anti-freeze Systems

High Rise Considerations

High Piled/Rack Storage (ESFR heads or other special heads) note see NFPA 231 & 231C.

Fire Pumps Standpipe and/or Hose Systems

Special Hazards Systems (A triple FFF, etc.).

Brian Melly's 7-step method for the review of hydraulic calculations, taken from his 1990 article, has been condensed and paraphrased as follows:

1. Compare the reference points on the plans against the hydraulic reference points in the calculations. Reference points should appear at all flowing sprinklers in the remote area, at fittings where flow splits occur, at points where C-value changes occur, and at all system water sources.
2. Verify the accuracy of the node table information on the hydraulic calculation sheet. Checks here include accuracy of K-factors, the inclusion of hose demand, the inclusion of all heads in the remote area, accurate GPM flows, reworked K-factors for pendent heads and/or arm-overs, and proper K-factors at all flow splits (such as riser nipples).
3. Verify that pipe lengths, pipe diameters, C-factors, and other pipe output data are accurate. Pipe fitting offsets must be represented and inputted correctly by the designer, as friction losses are considerable with flow direction changes.
4. Verify that the water flow path on the calculations matched the flow path on the drawings. Beginning at the most remote sprinkler head, highlight all the pipes identified on the hydraulic calculations. When you are finished, all piping with water flowing should be highlighted on the plan.
5. Determine if the water supply information for the sprinkler submittal is accurate at the point of connection. Also, determine if there is any significant elevation difference between the water supply flow test and the sprinkler system point-of-connection. You may wish to obtain a written water flow report.
6. Verify that the required water density identified on the drawing is being provided. Determine whether the amount of water supplied satisfies the density requirement for the entire remote area.
7. Check closely how the backflow preventor, water meter and fire pump were modeled in the hydraulic calculations. The losses for water meters and backflow devices should not be simulated using the hydraulic's program. The losses from these devices should be subtracted from the water supply information.

The reviewer must be cognizant of elevations, particularly the elevation of the (highest) sprinkler deflectors. With regard to Step 6, if the design criteria for the calculation is 0.19 gpm/sf over 1500 square feet, the total sprinkler demand needs to be $(.19 \times 1500)$ *at least* 285 gallons per minute, or else something is wrong. Usually, the sprinkler demand in such an instance is around 340-350 GPM, or around 320 GPM if piping is arranged on a grid. The reviewer also needs to make certain that the remote area used is in fact 1500 square feet, or

whatever is called for. Remote areas for dry systems must be 130 % of what is mandated by code. Also to be verified is the fact that the remote area utilized is actually the hydraulically most demanding area of the system.

It is importance when checking calculations to verify the type of piping being used. Results generated from the calculations vary a great deal depending on the interior diameters of the pipes, so it is critical to ensure that the pipe specified is correctly represented in the calculations. It is usually necessary to ask for cut sheets on the type of piping to be installed, this includes the underground piping. The designer may input nominal pipe sizes, so look for this. The I.D. of Class 150 enamel-line cast iron underground piping is actually 3.98 inches, not four inches as believed. In the instance of system additions, thin-wall feed mains may be installed, but that does not mean that the existing supply pipes are also thin-wall. The existing pipe is very often, Schedule 40 steel pipe, and this needs to be represented in the calculations, because it makes a big difference.

Some computer programs are easier to read than others, others are not as widely used, and therefore, may not be as familiar to you. But an effort has to be made to read the entire program. It isn't the designer's fault if you are not hydraulically adequate. It is your job to review the calculations.

In Step 7, make sure that you know the exact make and model of the backflow preventor being installed. Friction loss characteristics vary wildly depending on the exact type of device and the brand being installed.

The use of a preprinted form, onto which a number of various comments regarding deficiencies are noted may be used. But a plan review made in letter form is utilized more often. The letter typically has five parts to it.

The letter should begin with a paragraph or statements regarding the scope of the review. State exactly what has been reviewed and in conformance to what specific code or codes. This should be followed by a general discussion of the particulars of the building occupancy and the systems protecting that occupancy. This is the time to put into writing, the unique conditions involved, hydraulic characteristics, and any acceptable divergences undertaken in design. Note in this paragraph, if material data sheets need to be submitted and if there are any questions that you have as a reviewer concerning the plan. The letter should include a sentence regarding approval. The plans are either approved, rejected, or conditionally approved. If plans conform to code and specification except for several minor items, then conditional approval should be granted. The letter should numerically list the reviewers comments, mentioning the exact sections of the code or specification that the contractor has not adhered to. The letter should finish with a paragraph that includes comments regarding the required protocol for hydrostatic testing, naming the responsible party for final on-site field checking, and any other pertinent miscellaneous comments.

I have compiled several additional final "hints" to bear in mind and steer you towards expediency, efficiency, and quality:

- Focus on the major items of system adequacy. You do not want to overlook the fact that

the plan failed to show some major component such as a fire department connection, an inspector's test connection, or sprinklers omitted from some small room.

- Do not feel as though you are not doing your job if the review only requires one or two comments. The plan review is for the checking of overall conformance with the design concept of the project and does not relieve the contractor of his responsibilities outlined in the contract documents.
- Make absolutely certain that the water supply information is reliable, and that enough hydraulic data has been submitted. Usually, one hydraulic calculation is not enough, and it is certainly not enough for a building of mixed-use occupancy or multiple systems protection.
- Concentrate your efforts on issues vital to the integrity of the plan review, such as the hydraulic data and code conformance pertinent to sprinkler performance for the specific hazards.
- Review plans as early as possible with respect to the construction process.
- Never assume that a CADD-generated plan is a superior product. A plan prepared on CADD may have less information on it than a hand drawn plan. The computer does not know anything about sprinkler spacing, code specifics, or system design. If necessary details and information have not been inputted, it is your job to call these out.
- Nail down classification of occupancy for all areas. Focus on the hazard.
- On system additions, make reference to the necessity of coordinating future valve closures with our FPB.

Below is Russ Fleming's quick reference sheet for reviewing sprinkler plans, also known as "Twenty Questions." (published by National Fire Sprinkler Association (NFSA) in 1983).

1. Is the information sufficient to review plans?
2. Is the hazard and/or commodity classification proper for the occupancy?
3. Is the protection area per sprinkler within requirements for the appropriate hazard classification?
4. Are distances between the branch lines and between sprinklers on the branch lines within the maximum allowable? Are end sprinklers and end branch lines within the allowable distance from the walls?
5. Are sprinklers positioned within allowable deflector distances to ceilings? Are the clearances to obstructions proper?
6. Are sprinklers to proper temperature rating for maximum expected ceiling temperatures and proximity to unit heaters, skylights, etc.?
7. Has an inspector's test connection been provided at the end of each sprinkler system?
8. Has a fire department connection been provided and properly located?
9. Are sufficient pipe hangers properly located?
10. Are a sufficient number of systems provided to meet the maximum system size

requirements?

11. If a dry system, does the total system volume require a quick-opening device? Does the total system volume fall within specified limits or will a 60 second water delivery time need to be proven?
12. Is a system drain of adequate size provided?
13. Does the water supply data appear reasonably recent? Do the plans indicate when and where the last flow test was made and who performed it?
14. If a hydraulically designed system, do the design density and area meet the proper curve?
15. If hydraulically designed does the system demand point fall below the supply curve on the Flow Test Summary Sheet?
16. Are the pipe joining techniques and C-factor proper for the type of pipe and system?
17. Does the K-factor of the sprinklers shown on the drawings match that used in the hydraulic calculation?
18. Does the choice of hydraulically most remote area appear proper?
19. Are all sprinklers, valves, pumps, hangers, cut and roll grooved couplings and plain-end fittings listed for fire protection service? Does piping meet acceptable materials specifications?
20. Is complete sprinkler protection provided?

Bill Harris, a training coordinator that Western States Fire Protection utilizes, furnished the following information that Western's designer Mark Code utilizes in his designs that are being submitted to Cheyenne's FPB.

CALCULATION PROCEDURE FOR MANUAL CALCULATIONS

Hydraulic calculations cannot begin until the system has been laid out and the system cannot be laid out until the following information has been established.

A. The plans for the building have to be reviewed to determine the type of roof structure, the height of the building, the occupancy class of the building. The water supply information must be known at a minimum.

B. Establish the type of hazard. This can be from the specifications, the UFC or UBC, building official, from an insurance authority, or from NFPA codes. The hazard can be Light, Ordinary, Extra, or Special as High Pilled Storage.

C. A current water flow test is required for the city main that the system will connect to. Ensure that the water flow information provided by the Board of Public Utilities (BOPU) has at least one flow hydrant and a test hydrant.

D. See what system configuration, types of pipe, densities, etc. are being used.

E. Layout the sprinkler system with this information and once laid out the calculations can begin. In the real world the design may have to change numerous times because of coordination meetings with other trades or because of changes in the design of the building. These not only change the sprinkler head layout, but cause revision of the hydraulic calculations as well.

*Note. This is why the Fire Marshal requires as built drawings to be submitted prior to signing the acceptance paper work, or noted as a condition for the issuance of the building's Certificate of Occupancy (CO) by the Building Official.

F. The "Preliminary Hydraulic Worksheet" should be completed prior to beginning the actual hydraulic calculations, by computer or manually.

1. This worksheet can tell you if there is a problem with the water supply, and if a fire pump may be required.
2. Section "B" of this sheet can help determine the orifice size, and area per sprinkler based on the hazard being protected.
3. Section "C" of this sheet is used to set preliminary sizes for the mains and underground pipe.
4. Section "D" of this sheet is a good check to verify the elevation head in the system.

G. When the hazard classification is determined, the size of the remote area can be determined also. The remote area is not always the most remote (area farthest from the water supply) but should be the most demanding area based on GPM required and total pressure (PSI) required. You have to calculate the most demanding area in the system and may have to do several sets of hydraulic calculations to determine this.

H. For light and ordinary hazards, the remote area size used is 1500 square feet and for extra hazard it is 2500 square feet. NFPA 13, Figure 7-2.3.1.2 "Area/Density Curve" shows you can go up to 5000 square feet in the remote area and reduce the density required as the remote area size increases. Note that even though the density is smaller for the increased size for the area of coverage, that the total water flow demand is higher. The ratio of the increased area size to the density reduction is not equal. The total water demand increases as the remote area size increases. It is more economical, in most instances, to use the minimum square footage allowed for each hazard, because less water flow equals smaller pipe.

I. Once the size of the remote area is set, the shape has to be determined. NFPA requires that the length of the remote area that runs parallel to the branch lines be $1.2 \times \sqrt{1500}$ (for light and ordinary hazards) or 46.5'. Divide the remote area, 1500 square feet by the length; 46.5' equals 32.25' wide and is perpendicular to the branch lines. This is the starting point to set the remote area shape and size. The remote area cannot be shorter (the length parallel with the branch line) than $1.2 \times \sqrt{1500}$ (the remote area size for light or ordinary hazards) except when the branch line itself is actually shorter than the length determined by this formula. You can use $(1.2 \sqrt{1500} (RA) - \text{Head Spacing on Line} = \text{Number of Heads Across the Remote Area})$. The remote area cannot include a partial sprinkler head so the length has to be extended to include a whole sprinkler head. The border of the remote area has to be extended to the half way point between two sprinkler heads on a branch line or be at a blockage (a wall or beam). The width of the remote area is then based on the new length divided into the remote area. The borders for the width must fall at the mid-point between two lines or be at a blockage. Again the length of the remote area cannot be shorten too less than the minimum length found except as noted.

If the border of the remote area does not fall at a midpoint between two sprinklers it has to be extended to the midpoint between the next set of sprinkler heads, always longer and never shorter.

J. The shape of the remote area is generally rectangular in shape as derived from the formula in “I” above. In most instances the border of the remote area do not fall at a midpoint between sprinklers or branch lines. The length of the remote area, parallel with the branch line, is increased to be at the midpoint between two sprinklers and the width is adjusted to be between two branch lines. By this increase in length the square feet in the remote area is increased. Unless adjustments are made in the width of the remote area or in the shape of the remote area new size of the remote area will be large than required by codes. This increase in size may results in more sprinklers than are required to be in the remote area. Determine the number of sprinklers required in the remote area by multiplying the square footage coverage of the sprinkler (if all have the same spacing) by the number of sprinklers, at that square footage, in the revised remote area. Verify the size of the remote area to insure that the minimum square footage required is in the remote area. Verify that no partial sprinkler’s area of coverage is included in the remote area, but that only a whole sprinkler’s area of coverage is included. Adjust the size of the remote area to include only whole sprinklers and to not include to many sprinklers.

K. The remote area will not always be a rectangle in its shape. Many times there will be two or three lines with four or five sprinklers on each of the lines in the remote area and one line with only two or three sprinklers of this line required to make up the remote area. This results in an odd shaped area. When the branch lines are typical and one branch line requires fewer sprinklers than the other branch lines in the remote area then the sprinklers closest to the cross main are included in the remote area. The sprinklers toward the far end of the branch line are not included because they will flow less water than those sprinklers closest to the cross main. The remote area has to be the most demanding, so the most demanding sprinklers have to be calculated in the flow.

L. The above examples are for an open area with typical spacing for the sprinklers. When the remote area is one consisting of various sized offices or areas with the sprinklers not laid out typically, then each sprinklers area of coverage must be added together to make sure the total square feet in the remote area is protected. This is also a check to see if too many or too few sprinklers are included in the remote area. The border, parallel to the branch lines, of the remote area has to be $1.2 \times \sqrt{RA}$. The borders in this situation have to fall at the midpoint between sprinklers and branch lines or at a wall or other blockage for the sprinkler. The square footage is always the actual square footage of floor area to be protected in the remote area.

M. Once the remote area is laid out and verified, then the node numbers are added to the drawing. This is a guide for assigning node numbers to sprinklers and balance points. The sprinkler head can use “S1”, “S2”, ... To note the sprinklers in the remote area. If the sprinkler head is on a drop or sprig up then the balance point on branch line can be numbered “1”, “2”, ... To correspond to the number for the sprinkler head itself. Use letters for top of riser nipples, where the riser nipple connects to cross main, cross main to bulk main, and other junction points.

N. Hydraulic calculations begin at the most demanding sprinkler head and the calculations go back to the source against the direction of the water flow. Should the most demanding sprinkler not be the most remote sprinkler on a branch line the calculations should begin at the most remote sprinkler. Start at a high enough pressure with this sprinkler so that when you reach the most demanding sprinkler the demand (pressure and flow) is met. Hydraulic calculations being done by hand have to be in an orderly fashion to prevent missing a sprinkler or branch line. On the first sheet start with the most remote sprinkler and going against the water flow calculate back to the riser nipple or cross main. If sprinklers on the opposite side of the riser nipple or cross main are in the remote area then calculate them back to the common balance point. The water is combined and balanced at this point and calculated back to the next branch line, going against the water flow. This branch line is calculated on a separate sheet and the total flow is balanced to the pressure on the first sheet of calculations. With the combined flow the calculations are carried to next balance point and any additional water is added. The calculations continue through the cross main to the bulk main, to the riser, through the valves to the supply in the underground. We keep repeating that hydraulic calculations are always against the water flow in the system.

O. The following is a list of items to check when the hydraulic calculations are complete:

- 1.** The minimum end head pressure for most sprinklers is 7 PSI; some special sprinklers require higher minimum end head pressures. This is especially true of the ESFR sprinkler, extended coverage sprinklers, and of residential sprinklers. Verify that the correct end head pressure is available at each sprinkler head.
- 2.** Count the number of sprinklers flowing on the hydraulic calculation sheets, to make sure all of the sprinklers in the remote area are flowing.
- 3.** Make sure the remote area is at least the minimum size required for the hazard being protected and that its shape is the right length. $1.2 \times \sqrt{RA}$.
- 4.** Verify the correct density for the hazard being protected has been used.
- 5.** Check to see that each sprinkler in the remote area is flowing the correct amount of water based on the density and area of coverage.
- 6.** Make sure all parts of the system are connected in the hydraulic calculations.
- 7.** Verify that the correct “K” factor has been used.
- 8.** Use the correct “C” factor for dry and preaction systems and different types of pipe that may be used in the system.
- 9.** Add any fire hose allowance or rack sprinkler allowance to the water demand for the overhead sprinkler system calculations.
- 10.** Note all elevation changes and show the added or lost pressures in the calculations for these elevation changes.

11. Always pick up a fitting's equivalent feet when there is a change in direction of the water flow between two node numbers. For an elbow, use the smallest outlets of the elbow, equivalent feet in the hydraulic calculations. For a tee, when the water flow changes directions, the size of the outlet the water is now flowing out of is used to determine the equivalent feet used in the hydraulic calculations.

12. Draw a graph showing the city pressure and the system demand.

13. Pick up special devices with fixed losses, usually expressed in PSI; such as a backflow preventor in the calculations.

14. Use the friction loss chart for the correct type and schedule of pipe being used in the system. There may be schedule 40 pipe for drops, thread-able thin-wall for branch lines, schedule 10 for the mains, and PVC underground pipe.

15. Look for a section of pipe that has an unusually large friction loss for a potential problem, its size may have to be changed.

16. Verify that the size fittings used in the calculations are available in the market.

17. Keep water flow overage to minimum, preferably in the 10% range.

18. Many cities will require that the system pressure required at the connection to a city main not be less than 20 PSI residual pressure.

19. Only pick up a fitting in the calculations, when there is a change in water flow direction. There are two exceptions, one is when the fitting the sprinkler head is made into is not picked up as a change in direction (the fitting is already included in the "K" factor for the sprinkler head), and certain CPVC manufactures require that couplings and a straight run thru a tee be picked up and an equivalent footage be used for them. With the CPVC fittings this is done when there is no change in water flow direction.

20. Check each flowing sprinkler head in the remote area to determine that the sprinkler head is flowing the minimum GPM required for its density and spacing. If the most remote sprinkler head is flowing more water than required by its density and spacing, then the pipe size may have to be adjusted to get the flow closer to the actual required. This is to keep the water flow overage down in the system and the overall pipe sizes down. The pipe supplying the sprinkler head that is overflowing may have to be increased in size to get its flow down.

P. Preliminary Hydraulic Worksheet.

1. The Date, Engr./Tech., Project, and Project Number are to identify the project and who is doing it.

2. System No., No. Heads in System, and No. Heads In Remote Area (RA) are to

identify the system and remote area size.

3. Typical Head Spacing (if heads are spaced typically this represents the typical spacing. If the heads are not spaced in a typical manner then an average spacing can be used to obtain an average spacing).

4. Flow Test Data is for information received from city on water flow or results of your flow test.

5. Density (based on hazard) x Design Area (remote area) x Overage Factor (During actual calculations the water demand will grow due to pressure increase at each sprinkler head. The overage is figured as a percent in the 10% to 15% range) + System Demand (the GPM required for the system) + Other Demands (this can be for rack sprinklers, inside hose stations, etc.) = Total Demand (in GPM). By using the water flow graph the PSI available at the system, demand can be determined, PSI Available at System Demand on Flow Test (in PSI).

6. This line is used to determine the end head pressure of the sprinkler head. In the box for density enter the density, determine from the type hazard being protected x area per head (from typical head spacing above) = flow in GPM at end sprinkler head (divided by) the K factor used for the sprinkler head and then this answer is (squared) and it equals the end head pressure.

7. The next three lines are for the underground and overhead bulk mains in the system. Enter the total flow for the system and the pipe size to be used, then enter the friction loss for the flow and pipe size given (taken from the friction loss tables) x the length of the main = the friction loss for the mains in PSI.

8. Next is the elevation change, the pressure required to get water to the highest point in the systems (most remote sprinkler head). The elevation loss is .433 PSI per foot of elevation x the elevation change from the water supply point to the height of the most remote sprinkler head = the elevation loss in PSI.

General Information:

Gridded dry-pipe systems are no longer permitted for new installations, and are required to have a quick opening device when the systems volume exceeds 350 gallons. The dry-pipe valve and the water supply pipe must be protected against cold temperatures and mechanical injury. A heated enclosure is required for this purpose (40°F). The air pressure in the system should correspond to that listed on the instruction sheet for the dry-pipe valve or is 20 psi above the valve's calculated trip pressure. (NFPA Inspection Manual, 1994, pgs. 150 & 151).

In no case shall maximum water temperature flowing through the sprinkler portion of the system exceed 120°F.

If there are more than 20 sprinklers on a preaction system, the sprinkler piping and fire detection devices must be supervised automatically. Because a preaction system cannot have

more than 1,000 closed sprinklers, very large areas will require more than one preaction valve. The fire detection devices and systems of a deluge system also must be supervised automatically, regardless of the number of sprinklers on the system. (NFPA Inspection Manual, 1994, p. 151).

If the system does not rely on a fire pump, you may use this rule of thumb to estimate the water pressure. The readings should be at least 30 psi for a one story building and 5 psi for each additional story.

The gauges used on a sprinkler system must be replaced or tested every 5 years to verify their accuracy. A calibrator, or inspector's gauge, should be used to determine whether the system gauge is accurate to within 3% of the full-scale reading of that gauge. If not, re-calibrate or replace the gauge. (NFPA Inspection Manual, 1994, p. 153).

Where larger areas need to be protected, usually those which require an antifreeze system in excess of 40 gallons, small auxiliary dry-pipe systems usually become more economically advantageous. (NFPA Automatic Sprinkler Systems Handbook, p. 157).

For residential fire sprinkler systems, reference NFPA 13D & 13R. The

APPENDIX B

Hazard Classifications

Examples of light-hazard occupancies are apartment buildings, dormitories, office buildings, the seating areas of restaurants, and hospitals. In these occupancies, the potential rate of heat release is low, areas are usually subdivided, and a small number of sprinklers normally should control any fire. For hydraulically designed systems, 150 gpm for sprinkler operation and an additional 100 gpm for hose stream demand will make a good starting point for system demand. A total of 500 to 750 gpm for pipe schedule systems may be necessary for the same hazard, thereby making this a less desirable design approach.

Ordinary-hazard classification includes occupancies such as in garages, bakeries, laundries, and canneries, in which the combustibility of contents, though generally low, is greater than that for the light-hazard class.

Group 1: Occupancies will require a minimum of 240 gpm for sprinkler operation, and an additional 250 to support exterior hose streams. If a pipe schedule approach is selected, a minimum flow of 700 gpm is necessary.

Group 2: This ordinary-hazard classification includes occupancies such as clothing factories, mercantile, pharmaceutical manufacturing, and shoe factories. With this group, the combustibility of contents, storage heights, and obstruction features are generally unfavorable. Ordinary-hazard group 2 occupancies require a minimum flow of 285 gpm for sprinkler operation, plus an additional 250 gpm to operate exterior hose streams. If design is based upon the pipe schedule method, a minimum total flow of 850 gpm is necessary.

Group 3: This classification consists of occupancies where standard sprinkler spacing and pipe schedules are considered satisfactory, but where more-than-ordinary water supplies are advisable. This group includes certain wood-working occupancies and others such as flour and feed mills, paper mills, piers and wharves, and tire storage.

Extra-hazard occupancies consist of properties where flash fire opening all the sprinklers in a fire area are probable, calling for close sprinkler spacing and larger pipe sizes. They are divided into two groups.

Extra-hazard occupancies (Group 1) include those that may produce severe fires where few or no flammable or combustible liquids are present. These include such occupancies as die casting, plywood and particle board manufacturing, printing (using inks with below 100°F flash points), rubber manufacturing operations, saw mills, textile operations, and plastic foam manufacturing.

Extra-hazard occupancies (Group 2) include those that may produce severe fires where moderate to substantial amounts of flammable or combustible liquids are present, or where shielding of combustibles is extensive. These include such occupancy hazards as asphalt saturating, flammable liquids spraying, flow coating, open oil quenching, solvent cleaning and varnish and paint dipping.

Dry-pipe systems differ from basic wet-pipe systems in several ways. The water is kept from reaching the sprinklers by the pressure of compressed air or nitrogen acting on the system side of the valve. In areas subject to freezing, the dry-pipe pendent type of sprinkler can be used; standard pendent sprinklers are allowed only on return bends in heated areas. Dry-pipe systems with a capacity of more than 500 gallons must have quick-opening devices. Gridded dry-pipe systems are no longer permitted for new installations, and are required to have a quick opening device when the systems volume exceeds 350 gallons. The dry-pipe valve and the water supply pipe must be protected against cold temperatures and mechanical injury. A heated enclosure is required for this purpose (40°F). The air pressure in the system should correspond to that listed on the instruction sheet for the dry-pipe valve or is 20 psi above the valve's calculated trip pressure. (NFPA Inspection Manual, 1994, pgs. 150 & 151).

In no case shall maximum water temperature flowing through the sprinkler portion of the system exceed 120°F.

Types of Sprinkler Systems

Automatic sprinkler systems are considered to be the most effective and economical way to apply water to suppress a fire. There are four basic types of sprinkler systems.

1. A *wet-pipe system* is by far the most common type of sprinkler system. It consists of a network of piping containing water under pressure. Automatic sprinklers are connected to the piping such that each sprinkler protects an assigned building area. The application of heat to any sprinkler will cause that single sprinkler to operate, permitting water to discharge over its area of protection.
2. A *dry-pipe system* is similar to a wet system, except that water is held back from the piping network by a special dry-pipe valve. The valve is kept closed by air or nitrogen pressure maintained in the piping. The operation of one or more sprinklers will allow the air pressure to escape, causing operation of the dry valve, which then permits water to flow into the piping to suppress the fire. Dry systems are used where the water in the piping would be subject to freezing.
3. A *deluge system* is one that does not use automatic sprinklers, but rather open sprinklers. A special deluge valve holds back the water from the piping, and is activated by a separate fire detection system. When activated, the deluge valve admits water to the piping network, and water flows simultaneously from all of the open sprinklers. Deluge systems are used for protection against rapidly spreading, high hazard fires.
4. A *preaction system* is similar to a deluge system except that automatic sprinklers are used, and a small air pressure is usually maintained in the piping network to ensure that the system is air tight. As with a deluge system, a separate detection system is used to activate a deluge valve, admitting water to the piping. Because automatic sprinklers are used, however, the water is usually stopped from flowing

unless heat from the fire has also activated one or more sprinklers. Some special arrangements of preaction systems permit variations on detection system interaction with sprinkler operation. Preaction systems are generally used where there is special concern for accidental discharge of water, as in valuable computer areas.

These four basic types of systems differ in terms of the most fundamental aspect of how the water is put into the area of the fire. There are many other “types” of sprinkler systems, classified according to the hazard they protect (such as residential, in-rack or exposure protection); additives to the system (such as antifreeze or foam); or special connections to the system (such as multipurpose piping); but all sprinkler systems can still be categorized as one of the basic four types.

Preaction and deluge systems use a supplemental detection system to initiate the flow of water. In a preaction system, only one or a few sprinklers will open; in a deluge system, all the sprinklers discharge simultaneously. When checking the location and spacing of fire detection devices, as well as the functions of the system, you should refer to the manufacturer’s literature, the listing criteria, and the appropriate installation standards such as NFPA 72, National Fire Alarm Code. If there are more than 20 sprinklers on a preaction system, the sprinkler piping and fire detection devices must be supervised automatically. Because a preaction system cannot have more than 1,000 closed sprinklers, very large areas will require more than one preaction valve. The fire detection devices and systems of a deluge system also must be supervised automatically, regardless of the number of sprinklers on the system. (NFPA Inspection Manual, 1994, p. 151).

If the system does not rely on a fire pump, you may use this rule of thumb to estimate the water pressure. The readings should be at least 30 psi for a one story building and 5 psi for each additional story. On a wet-pipe system, the system gauge should read the same, or in some cases, slightly higher than the supply gauge. On a dry-pipe system, the system pressure is the pressure of the air or nitrogen and usually is considerably less than the water supply pressure. The gauges used on a sprinkler system must be replaced or tested every 5 years to verify their accuracy. A calibrator, or inspector’s gauge, should be used to determine whether the system gauge is accurate to within 3% of the full-scale reading of that gauge. If not, re-calibrate or replace the gauge. (NFPA Inspection Manual, 1994, p. 153).

There are four types of fire sprinkler systems listed in NFPA’s Automatic Sprinkler Hand Book, (1) wet-pipe systems, (2) dry-pipe systems, (3) preaction and deluge systems, and (4) combined dry-pipe and preaction systems. (NFPA, 1991, pgs. 113 - 132).

There are four basic types of sprinkler systems, (1) wet-pipe, (2) dry-pipe, (3) deluge, and (4) preaction. Wet-pipe systems contain water in the system at all times. Dry-pipe systems maintain air under pressure in the sprinkler piping. When sprinklers fuse, air escapes and water is automatically admitted into the system. A preaction system is a type of dry-system that employs a deluge-type valve, fire detection devices, and closed sprinklers. This system only discharges water into the piping in response to a signal from the detection system. Water is then discharged onto the fire

when individual sprinklers open. The deluge system is another type of dry-pipe system. It is equipped with open sprinklers and a deluge valve. Upon fire detection, the deluge valve opens, permitting water to flow from all sprinklers at once. (IFSTA, 2001, p. 162).

In a dry-pipe system, the piping is not filled with water but rather air or nitrogen which is under pressure. As with wet-pipe systems, closed automatic sprinklers are used. The operation of a sprinkler will cause depletion of the system air pressure which in turn will open the dry-pipe valve and allow water to enter the piping. Dry-pipe systems are usually used in buildings or in areas which are subject to freezing. They are more complex than wet-pipe systems and require greater attention regarding their design, installation, and maintenance. (NFA, Fire Protection Systems and Equipment, 1991, p. 135).

Preaction systems are more technical in nature and require specialized knowledge and experience with their design and installation. Manufacturer's specifications and listings must be strictly adhered to. Since these systems contain more components and are more complex than wet or dry-pipe systems, failure to maintain them properly will seriously reduce their reliability. Initial installation cost as well as long-term maintenance costs of these systems should be considered. The supplemental equipment necessary to operate these systems also results in increased economic concerns that must be considered. (NFA, Fire Protection Systems and Equipment, 1991, p. 145).

Deluge systems are normally reserved for use in very high hazard areas. These systems have properties similar to those of a preaction system in that they rely on a supplemental detection system to operate them. They however use open sprinklers. NFPA 409, Standard on Aircraft Hangars, requires the installation of foam-water deluge systems in critical hangars. These systems may be operated by heat detection systems or UV and IR detection systems. (NFA, Fire Protection Systems and Equipment, 1991, p. 151).

Antifreeze systems are typically used within wet-pipe systems for limited building areas which may be exposed to freezing temperatures such as outside loading docks. They are more economically attractive than dry-pipe systems. However, where larger areas need to be protected, usually those which require an antifreeze system in excess of 40 gallons; small auxiliary dry-pipe systems usually become more economically advantageous. (NFPA, Automatic Sprinkler Systems Handbook, p. 157).